DOCTORAL THESIS

Age-related Decline: Detecting Mild Cognitive Impairment

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Age-related decline: Detecting mild cognitive impairment

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Abstract

Over the past decade, increased attention has been given to precursors to Alzheimer's disease. Individuals within this intermediate stage often have some form of deficit in cognitive functioning, but do not meet the criteria for Alzheimer's disease. Contrary to earlier research that indicates cognitive decline occurs after the age of 65, there is evidence to suggest that it may begin as early as the second decade of life (e.g., Murre, Janssen, Rouw, & Meeter, 2013). The aims of the current research were to investigate the nature and onset of cognitive decline. There is some evidence that organic processes associated with aging affect the entire brain, resulting in a general degradation of overall cognitive function, or a *generalised decline*. An alternate view is that some neurological structures may appear to decline more rapidly than others, suggesting they are more vulnerable to decline or are differentially affected by the disease process. For example, if decline in nonverbal memory is observed but verbal memory remains intact, this would provide evidence for dissociation of memory processing and support a theory that age related changes occur in distinctive parts of the brain that decline at different rates. This could be described as *modular decline.* The deeper understanding of the nature and onset of cognitive decline should allow for more effective treatment or intervention pathways and also aid in the development of more sensitive instrumentation in the detection of cognitive decline.

A series of five studies were conducted assessing cognitive domains that are claimed to decline with age. Four of the studies were conducted independently from 2010 to 2013. Each of the studies comprised different participants in the main with slight overlaps that are detailed in the methodology chapter of the thesis. There is some evidence (e.g., Sorrel & Pennequin, 2008) for incipient decline of executive functioning and hence this was the focus of the preliminary investigation. Seventy-five participants (50 females and 25 males) aged 18 to 82 years (M = 46.49, SD = 20.61) were recruited from South-Eastern Australia. Forty-two

participants (56.0%) nominated high school, 25 (33.3%) nominated university, 7 (9.3%) nominated T.A.F.E/college and 1 (1.3%) nominated primary school as highest level of education obtained. For the entire sample, 26 participants (34.7%) were taking medication for illnesses e.g., high blood pressure, high cholesterol, diabetes, depression, vascular problems and 49 (65.3%) were not taking medication.

The participants were divided into three groups depending on age. The younger adults group (18-49) consisted of 35 participants aged 18 to 48 (M = 26.43, SD = 9.50) with 25 females and 10 males. From the sample, 20 (57.1%) participants nominated high school, 12 (34.3%) university and 3 (8.6%) nominated T.A.F.E. or College as the highest level education obtained. Two of the participants (5.7%) were taking medication for illnesses e.g., high blood pressure, high cholesterol, diabetes, depression, vascular problems. Thirty-three (94.3%) participants were not taking medication.

The middle adults group (50 to 64) consisted of 21 participants aged 51 to 64 (M = 58.30, SD = 4.23) with 15 females and 6 males. From the sample, 8 participants (40.0%) nominated high school, 9 (45.0%) university and 3 (15.0%) T.A.F.E/College as highest level of education obtained. Ten (50.0%) of the participants were taking medication for illnesses e.g., high blood pressure, high cholesterol, diabetes, depression, vascular problems. Ten (50.0%) participants were not taking medication.

The older adults group (65 and above) consisted of 20 participants aged 66 to 82 (M = 69.80, SD = 4.05) with 10 females and 10 males. From the sample, 14 (70.0%) nominated high school, 4 (20.0%) university, 1 (5.0%) T.A.F.E/College and 1 (5.0%) nominated primary school as highest level of education obtained. Fourteen (70.0%) of the participants were taking medication for illnesses e.g., high blood pressure, high cholesterol, diabetes, depression, vascular problems. Six (30.0%) participants were not taking medication.

Participants were administered computerised tasks assessing executive functioning and short-term memory. As expected there was evidence of an age related decline in executive functioning whilst short-term memory performance remained unaffected. This may be indicative that certain subsystems are differentially sensitive to age cognitive decline.

It has been claimed that one's ability to recognise emotion declines with age (e.g., Ruffman et al., 2008). Deficits in emotion recognition may provide insight into what is occurring in the ageing brain. This study investigates whether changes in recognition of emotion could be attributed to a decline in memory processes. Based on previous literature (e.g., Smith & Winograd, 1978), it was expected that decline in emotion recognition could be attributed to decline in non-verbal rather than verbal memory.

Sixty-two participants (48 females and 14 males) aged 18 to 84 years (M = 50.47, SD = 20.83). For the entire sample, 28 participants (45.2%) were taking medication for illnesses e.g., high blood pressure, high cholesterol, diabetes, depression, vascular problems and 34 (54.8%) were not taking medication. Forty-one (66.1%) nominated high school, 13 (21.0%) nominated university, 6 (9.7%) nominated T.A.F.E/college and 2 (1.3%) nominated primary school as highest level of education obtained.

The participants were divided into three groups depending on age. The younger adults group (18-49) consisted of 21 participants aged 18 to 49 (M = 24.71, SD = 9.32) with 18 females and 3 males. From the sample, 17 (81.0%) participants nominated high school and 4 (19.9%) and 3 (8.6%) university as the highest level of education obtained. One participant (4.8%) was taking medication for illnesses e.g., high blood pressure, high cholesterol, diabetes, depression, vascular problems. Twenty (95.2%) participants were not taking medication.

The middle adults group (50 to 64) consisted of 21 participants with ages ranging from 50 to 64 (M = 57.29, SD = 4.60) with 18 females and 3 males. From the sample, 9

participants (42.9%) nominated high school, 6 (28.6%) university, 5 (23.8%) T.A.F.E. /College and 1 (48%) as highest level of education obtained. Nine (42.9%) of the participants were taking medication for illnesses e.g., high blood pressure, high cholesterol, diabetes, depression, vascular problems. Twelve (57.1%) participants were not taking medication.

The older adults group (65 and above) consisted of 20 participants with ages ranging from 65 to 84 (M = 70.35, SD = 4.42) with 12 females and 8 males. From the sample, 15 (75.0%) nominated high school, 3 (15.0%) university, 1 (5.0%) T.A.F.E/College and 1 (5.0%) nominated primary school as highest level of education obtained. Eighteen (90.0%) of the participants were taking medication for illnesses e.g., high blood pressure, high cholesterol, diabetes, depression, vascular problems. Two (10.0%) participants were not taking medication.

Participants were administered computer tasks assessing emotion recognition, verbal and non-verbal memory. Emotion recognition declined in older adults for angry, surprised and fearful faces. Contrary to expectations, it was found there was age related decline in verbal memory. This suggests a common element present in verbal memory may also be involved in the process of emotion recognition. However, no concomitant decline in non-verbal memory was observed. As there was evidence of decline in emotion recognition and verbal memory with preservation of non-verbal memory, this suggests that age related decline is non-uniform or modular in nature.

Although there was no evidence of decline in non-verbal memory, this did not exclude the possibility of decline in the visual system contributing to changes in emotion processing. A further possibility is that older adults may have difficulty in processing the emotional content of stimuli. Therefore, these aspects of emotion processing were investigated. It was assessed whether older adults have difficulty in processing characteristics of a face, using a facial discrimination task. Further, it was assessed whether

older adults have difficulty in the processing of emotional content of stimuli, using a valence priming methodology. Seventy-three participants (52 females and 21 males) aged 19 to 82 years (*M* = 51.44, *SD* = 19.70) were recruited from South-Eastern Queensland. For highest education obtained, 50 (68.5%) participants nominated high school, 14 (19.2%) university, 6 (8.2%) nominated T.A.F.E/college and 3 nominated primary school (4.1%). From the participants, 36 (49.7%) were currently taking medication for illnesses e.g., high blood pressure, high cholesterol, diabetes, vascular problems. The other 37 participants (50.7%) were not currently taking medication.

The participants were divided into three groups depending on age. The younger adults group (18-49) consisted of 26 participants aged 19 to 47 (*M* = 27.58, *SD* = 9.14) with 20 females and 6 males. From the sample, 18 (69.2%) participants nominated high school, 5 (19.2%) university, 2 (7.7%) nominated T.A.F.E/College and 1 (3.8%) nominated primary school as the highest level education obtained. Two of the participants (92.3%) were taking medication for illnesses e.g., high blood pressure, high cholesterol, diabetes, depression, vascular problems. Twenty-four (92.3%) participants were not taking medication.

The middle adults group (50 to 64) consisted of 24 participants aged 50 to 64 (*M* = 58.25, *SD* = 4.74) with 17 females and 7 males. From the sample, 15 participants (62.5%) nominated high school, 5 (20.8%) university and 4 (16.7%) T.A.F.E/College as highest level of education obtained. Sixteen (66.7%) of the participants were taking medication for illnesses e.g., high blood pressure, high cholesterol, diabetes, depression, vascular problems. Eight participants (55.7%) were not taking medication.

The older adults group (65 and above) consisted of 23 participants aged 65 to 82 (*M* = 71.30, *SD* = 3.87) with 15 females and 8 males. From the sample, 17 (73.9%) nominated high school, 4 (17.4%) university and 2 (8.7%) nominated primary school as highest level of education obtained. Eighteen (78.3%) of the participants were taking medication for illnesses

e.g., high blood pressure, high cholesterol, diabetes, depression, vascular problems. Five (21.7%) participants were not taking medication.

Participants were administered computerised tasks assessing emotion recognition, emotion processing and visual processing. Contrary to expectations, no decline in emotion processing was observed. However, there was some indication of decline in visual processing and that older people might process the totality of the stimulus, rather than features. The finding that older adults process the whole face may be indicative that as we age, we simply process the general rather than paying attention to the detail. One interpretation of this finding is that older participants process stimuli holistically rather than by attending to specific surface features.

Recently it has been suggested (e.g., Hudon et al., 2006) that as we age we remember the general detail of the stimuli, rather than the specific details. Greater frequency of gist errors in aged populations have been claimed to be indicative of changes in memory. Sixty-six participants (49 females and 17 males) aged 18 to 86 years (M = 50.06, SD = 21.52) were recruited from South-Eastern Queensland. For highest education obtained, 42 (63.6%) participants nominated high school, 17 (25.8%) university, 5 (7.6%) nominated T.A.F.E/college and 2 nominated primary school (3.0%). From the participants, 35 (53.0%) were currently taking medication for illnesses e.g., high blood pressure, high cholesterol, diabetes, vascular problems. The other 31 participants (47.0%) were not currently taking medication.

The participants were divided into three groups depending on age. The younger adults group (18-49) consisted of 24 participants aged 18 to 46 (M = 24.13, SD = 8.13) with 22 females and 2 males. From the sample, 19 (79.2%) participants nominated high school, 3 (12.5%) university, 1 (4.2%) nominated primary school and 1 (4.2%) nominated T.A.F.E/College as the highest level education obtained. One of the participants (4.2%) was

taking medication for illnesses e.g., high blood pressure, high cholesterol, diabetes, depression, vascular problems. Twenty-three (95.8%) participants were not taking medication.

The middle adults group (50 to 64) consisted of 20 participants aged 50 to 64 (*M* = 57.40, *SD* = 5.13) with 14 females and 6 males. From the sample, 9 participants (45.0%) nominated university, 8 (40.0%) high school, and 3 (15.0%) T.A.F.E/College as highest level of education obtained. Eleven (52.4%) of the participants were taking medication for illnesses e.g., high blood pressure, high cholesterol, diabetes, depression, vascular problems. Nine (45.0%) participants were not taking medication.

The older adults group (65 and above) consisted of 22 participants aged 65 to 86 (*M* = 71.68, *SD* = 5.33) with 13 females and 9 males. From the sample, 15 (68.2%) nominated high school, 5 (22.7%) university, 1 (4.5%) nominated T.A.F.E/College and 1 (4.5%) nominated primary school as highest level of education obtained. Twenty-one (95.5%) of the participants were taking medication for illnesses e.g., high blood pressure, high cholesterol, diabetes, depression, vascular problems. One (4.5%) participant was not taking medication.

Participants were administered computerised tasks assessing non-verbal and verbal gist. As predicted, older adults recognised fewer target stimuli than young and middle old adults on the non-verbal gist task. They also recognised more semantically related items than middle and older adults. This is also consistent with the notion that older adults are more likely to remember the general idea, rather than the specific detail. In addition, both middle and older adults recognised more semantically related items than younger adults on the verbal gist task. Contrary to expectations, older adults recognised more target stimuli than the young adults. It is possible that this might be indicative of sampling bias in the younger adult cohort. Despite this outcome, the finding that older adults have a propensity to make gist errors was supported.

The effects of age related decline on implicit and explicit memory processes were investigated in the final study. From the literature (e.g., Spaan & Raajmakers, 2011), there is some indication that memory for implicit material is invariant with age. However, the second and third studies identified that older adults have decline in span. Therefore, it was predicted that age related decline would more likely be observed in explicit rather than implicit memory processing. Sixty-six participants (49 females and 17 males) aged 18 to 86 years (M = 50.27, SD = 21.06) were recruited from South-Eastern Queensland. For highest education obtained, 40 (60.6%) participants nominated high school, 17 (25.8%) university, 5 (7.6%) nominated T.A.F.E/college and 4 nominated primary school (6.1%). From the participants, 36 (30.45%) were currently taking medication for illnesses e.g., high blood pressure, high cholesterol, diabetes, vascular problems. The other 30 participants (45.5%) were not currently taking medication.

The participants were divided into three groups depending on age. The younger adults group (18-49) consisted of 24 participants aged 18 to 46 (M = 25.04, SD = 8.2) with 22 females and 2 males. From the sample, 18 (75.0%) participants nominated high school, 3 (12.5%) university, and 3 (12.5%) nominated primary school as the highest level education obtained. One (4.2%) of the participants was taking medication for illnesses e.g., high blood pressure, high cholesterol, diabetes, depression, vascular problems. Twenty-three (95.8%) participants were not taking medication.

The middle adults group (50 to 64) consisted of 21 participants aged 50 to 64 (M = 57.38, SD = 5.00) with 15 females and 6 males. From the sample, 9 participants (42.9%) nominated university, 8 (38.1%) high school, and 4 (12.5%) T.A.F.E/college as highest level of education obtained. Nine (42.9%) of the participants were taking medication for illnesses e.g., high blood pressure, high cholesterol, diabetes, depression, vascular problems. Twelve (42.9%) participants were not taking medication.

The older adults group (65 and above) consisted of 21 participants aged 65 to 86 (*M* = 72.00, *SD* = 5.24) with 12 females and 9 males. From the sample, 14 (66.7%) nominated high school, 5 (23.8%) university, 1 (4.8%) nominated T.A.F.E/College and 1 (4.8%) nominated primary school as highest level of education obtained. Twenty (95.2%) of the participants were taking medication for illnesses e.g., high blood pressure, high cholesterol, diabetes, depression, vascular problems. One (4.2%) participant was not taking medication.

Participants were administered computerised tasks assessing implicit and explicit memory. Consistent with expectations, no age differences were identified on verbal or non-verbal implicit tasks, suggesting that memory for implicit material remains preserved. Older adults were found to have a lower span than younger adults, which is indicative of decline in explicit memory. This finding is consistent with a view of modular decline with increasing age.

The thesis discussed limitations of the current design and investigated domains of cognition likely to have diagnostic utility for early detection of cognitive decline. From the results obtained, a modular model is endorsed with cognitive reserve masking decline in certain circumstances. Consistent with recent research, there is evidence of decline as early as the second decade of life. This thesis has also outlined a potential pathway for the development of further research into the area of aging.

This work has not been previously submitted for a degree or diploma at this or any other university. This thesis contains no material that has been previously published or written by another person however when due reference is made in the thesis itself

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Victoria Alexander

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Chapter 1: Introduction

Historical Overview

Over the past decade, increased attention has been given to precursors to Alzheimer's disease (Petersen, 2004). The intermediate state of functioning before the diagnosis of Alzheimer's disease is often referred to as mild cognitive impairment (MCI). Mild cognitive impairment is thought to reflect the period of decreased cognitive functioning that precedes dementia and can be differentiated from typical age related decline (Petersen, 2004, 2011). Observations of this type of decline have been previously reported as dementia prodrome, incipient dementia, benign senescence, isolated memory impairment, and age associated cognitive decline. However, it is still unclear if these labels represent a single phenomenon, discrete phenomena or simply variation across the continuum of the normal aging spectrum, as opposed to pathologic aging (Petersen et al., 2001; Petersen, 2004; Petersen & Morris, 2005).

The term mild cognitive impairment was devised to differentiate those individuals who function normally, despite having a form of memory impairment and who fail to meet the diagnostic criteria for dementia[1] (Flickr, Ferris, & Reisberg, 1991; Petersen et al., 2001; Petersen, 2004; Petersen, 2011). A reasonably current criteria for mild cognitive impairment as conceptualised by Petersen (2011) is as follows:

1) Subjective report of cognitive complaint by the patient that is also corroborated by a close informant
2) Change in cognition that is considered not normal
3) Preservation of functional abilities with slight impairment
4) Is not demented

[1] DSM-V now refers to this as major neurocognitive disorder

However, there are potential concerns with using these criteria. There is likely to be a high level of personal subjectivity in relying on the individual and family members to corroborate impairment. A family member's perspective is likely to be biased, which may result in an individual being incorrectly classified as impaired. A further concern is that many alternative assessment methods have been designated for assessing cognitive decline and instrument bias may result in different assessments of level of functioning. These may not be large differences, but sufficiently variant to problematise diagnosis. There is also no consistent operational definition of what is defined as *preservation of functional abilities* and *not demented*. Petersen and others (e.g., Luis, Loewenstein, Acevedo, Barker, & Duara, 2003) also emphasise the role of clinical judgment in assessing whether a person meets the criteria for mild cognitive impairment. The subjectivity of clinical judgment may contribute to false positives or false negatives in diagnosis. That is, different clinicians may have a bias to over or under diagnose and consequently, the error in diagnosis is potentially high. The development of a sensitive, objective instrument that is able to detect the earlier onset of decline would increase accuracy and enable a better basis for differential diagnosis. The development of such instruments requires greater understanding of the nature of early cognitive decline and its onset. One point of differentiation of early cognitive decline is the differentiation of decline associated with specific cognitive functions.

Mild cognitive impairment subtypes were developed to differentiate the potential for different trajectories due to the heterogeneity of the population: Amnestic mild cognitive impairment in which the impairment is primarily associated with memory loss, and non-amnestic mild cognitive impairment in which the impairment is associated with a non-memory domain (e.g., language, praxis, and visuospatial abilities; refer to Figure 1 below). Both subtypes may have impairment of either single or multiple cognitive domains. It is thought that the deficit presenting in early decline will presage the development of future

dementia. Petersen (2011) posits that non-amnestic mild cognitive impairment is less common than the amnestic type and not as likely to be associated with Alzheimer's disease. Refer to Figure 1 below for a visual representation of Petersen's classification.

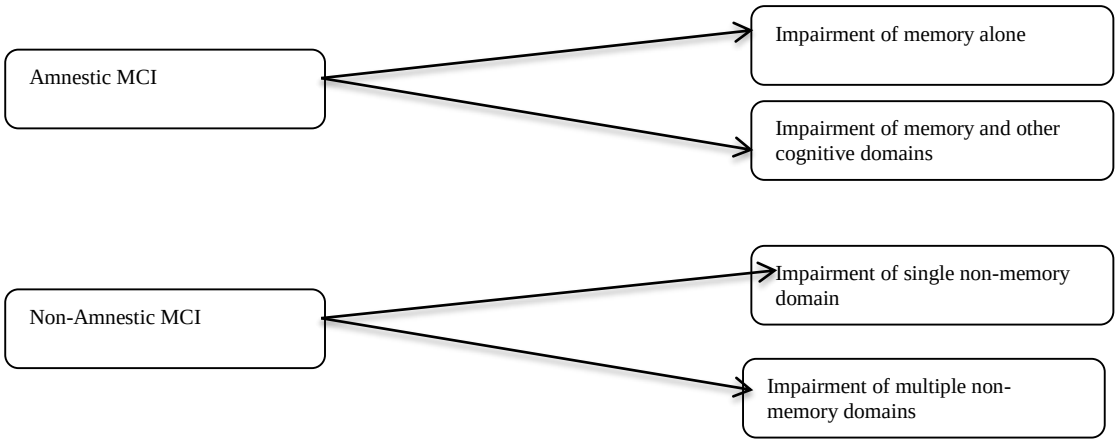

Figure 1. Subtypes of Mild Cognitive Impairment adapted from Petersen (2011).

Consequences and Rationale for Studying Mild Cognitive Impairment

A diagnosis of Alzheimer's disease is likely to have a detrimental impact on an individual, such as the ability to function independently. As the older individual is unable to look after his or her own needs, this may lead to institutionalisation. Institutionalisation is also likely to increase economic burden (both personal and social), as intensity of care and duration of care is likely to increase. Institutionalised individuals are also likely to experience rapid cognitive deterioration and reduced quality of life (Formiga et al., 2009; St John, Montgomery, Kristjansson, & McDowell, 2002). Research has also shown that even individuals with cognitive scores in the low normal range are at risk of experiencing adverse outcomes such as fully developed dementia and institutionalisation (St John et al., 2002). Therefore, it would be beneficial to be able to detect mild cognitive impairment in its early stages, so that strategies can be implemented which may improve quality of life and level of independence (Luis et al., 2003). Early diagnosis could also allow time for important life decisions that an individual would need to consider (such as designating power of attorney and guardianship, financial planning) as well as addressing safety concerns such as whether

they are still competent to drive (Brodaty, Low, Gibson, & Burns, 2006; Petersen & Morris, 2005). It may also help reduce psychological, social and financial burdens that are associated with looking after the individual.

Previously it was thought that cognitive decline may start to occur towards late adulthood, however, there is some evidence that it may begin earlier. Salthouse (2011) posits based on review of other work, that decline in cognitive functioning can occur prior to the age of 65. Park, Lautenschlager, Hedden, Davidson, and Smith (2002) found evidence for decline in processing-intensive tasks started as early as the second decade of life (e.g., working memory and long term memory). Murre, Janssen, Rouw, and Meeter (2013) also identified decline in overall memory performance after the age of 25. In addition, the authors claimed that visuo-spatial memory was found to decline from the age of 18 and occurred twice as fast as verbal memory. This may be indicative that the disease process may begin in early adulthood, rather than at the later spectrum of aging.

Although there are currently no effective treatments for Alzheimer's disease, there are pharmacological interventions (e.g., cholinesterase inhibitors), as well as mediating behavioural interventions such as exercising and staying mentally active (e.g., doing crossword puzzles, reading books and newspapers and engaging in regular physical activity) which can be implemented and may potentially slow the progression of the disease (Boote, Lewin, & Beverley, & Bates, 2006; Cramer et al., 2012; Cruz-Oliver & Morley, 2010; Wilson et al., 2002). Both the pharmacological pathway and the behavioural pathway lead to options for improving quality of life in an ageing population. The pharmacological pathway may preserve cognitive function longer, whereas the behavioural pathway maximizes remaining function and quality of life.

Age Related Cognitive Decline: Generalised and Modular

It has been proposed that organic processes associated with aging, such as the buildup of amyloid plaque, attack neurological structures indiscriminately, leading to generalised damage across the brain (Hardy, 2002). Under this model, the brain as a system is subject to *generalised decline.* A second view is that there is order to the decline, inconsistent with general degrading of overall cognitive function. That is, some aspects of cognition appear to decline more rapidly than others, suggesting structures associated with that type of processing are more vulnerable to decline or are differentially affected by the disease process (Delaloye et al., 2009). Under this model, decline of cognitive function might be expected to be more ordered and predictable than in generalised decline. This could be described as a *modular decline*. A third interpretation from the latter perspective is that rather than different parts of the brain declining non-uniformly, random damage might occur in one type of process without others being affected (e.g., similar to the specific aphasias that can occur as the result of a transient ischemic attack). For example, Sacks (1998) described an individual with damage to his brain who consequently had difficulty in recognizing people and objects, even mistaking his wife for a hat. However, other parts of his brain were seemingly unaffected and there appeared to be no other signs of cognitive deficit. This may indicate that decline in functioning can occur in some areas, whilst others remain unaffected from the disease process.

The following disease process models have been identified as being potential candidates for explaining age related cognitive decline. (Refer to Table 1 below).

Table 1

Disease Process Models for Explaining Age Related Cognitive Decline

Perspective	Model
Amyloid β	Generalised
Arterioscleoris[1]	Generalised/Modular
Processing Speed	Generalised
Reduced Processing Resources	Generalised
Executive Functioning Decline/Prefrontal Cortex Function	Modular

[1]**NB:** Arteriosclerosis has been placed under generalised decline because major blood vessels are likely to damage many subsystems across the entire brain. However, on occasion they may cause specific or localised transient attacks and therefore could also be considered modular.

Generalised Perspectives

Amyloid β.

The *amyloid β hypothesis*, posits that the accumulation of amyloid β in the brain tissue is the primary influence of AD pathology (Hardy, 2002). (Refer to Table 1 above). The buildup of amyloid β is thought to contribute to the formulation of neurofibrillary tangles containing tau protein (Hardy, 2002). The deposition of amyloid β appears to occur at the same rate in both healthy and unhealthy populations. However, it has been suggested that the rate of clearance of protein buildup is impaired in an unhealthy population and it is this failure to clear the protein that results in the buildup of plaque tangles characteristically reported in Alzheimer's disease (Zlokovic et al., 2005). Recent research suggests that sleep may aid in the clearance of amyloid β from the central nervous system (Xie et al., 2013). In addition, Spira et al. (2013) found older adults who reported shorter duration and poorer sleep quality had greater amyloid β buildup than individuals who reported longer duration and better quality sleep.

The buildup of amyloid β in the central nervous system is thought to cause cognitive deficit such as memory loss (Hardy, 2002; Lim et al., 2012). This was supported by the

research of Lim et al. (2012), who found that older individuals with high cerebral amyloid β load had greater episodic and working memory decline after 18 months, compared to healthy individuals with normal cerebral amyloid β load. In addition, although individuals carrying the APOE E4 allele[2] had more significant decline on episodic memory than those not carrying the allele, the magnitude of cognitive decline was larger for those individuals that had higher cerebral amyloid β load.

There is also some evidence to suggest that amyloid β build up may predict the later onset of cognitive impairment. Roe et al. (2013) using a sample of 202 individuals aged 45 and older, found cognitively normal individuals who had abnormal levels of biomarkers (Ab42, tau, ptau181, tau/Ab42, ptau181/Ab42) present at initial testing, developed symptomatology of cognitive decline up to 7.5 years later. However, it was found that some individuals who had normal biomarkers at initial testing also developed cognitive impairment. They also found some individuals who had abnormal biomarker levels that did not develop cognitive impairment at follow-up. This may be indicative that biomarker testing is not completely accurate in the detection of cognitive decline. Moreover, this method of screening is not easily accessible, and is costly and invasive (as biomarkers are derived through lumbar puncture).

Arteriosclerosis.

Decline in cognitive functioning may also result from vascular changes in the brain, such as *arteriosclerosis.* (Refer to Table 1 above). It is thought that stiffening (primarily of the aorta) leads to the transmission of flow pulsations, specifically into the kidneys and brain, where the energy is dissipated. This is likely to cause micro infarcts and microhaemorrhages, which subsequently may result in cell damage, renal failure, and of interest to the current work, cognitive decline (O'Rourke, 2007). Scuteri et al. (2007) suggest that hypertension is

[2] Allele associated with Alzheimer's disease

also a contributing factor, and that an increase in blood pressure further exacerbates arterial stiffness. However, Kearney-Schwartz et al. (2009) found arterial stiffening was independent of whether individuals had high blood pressure.

The association between arterial stiffening and cognitive decline was supported by Fujiwara et al. (2005), who found older adults that had a higher pulse velocity (a measure of arterial stiffness), had decline in cognitive function. Kearney-Schwartz et al. (2009) after adjusting for cardiovascular risk factors, also found arterial stiffness (measured by pulse wave velocity) was independently associated with memory impairment. However, this effect was only found for the male participants of the study.

Pase et al. (2010) assessed the relationship of arterial stiffness (pulse pressure and augmentation index) and cognition using middle-aged participants (40-65). Pase et al. found that pulse pressure was a predictor of episodic secondary memory and speed of memory, whilst augmentation index also predicted speed of memory. It was found that neither the augmentation index nor the pulse pressure predicted any of the other cognitive factors. Although there is some evidence linking arterial stiffness with cognitive decline, it is speculated that not all individuals with deficit have suffered some sort of vascular event, suggesting other processes must be involved.

Processing speed.

The *processing speed hypothesis* posits that as older adults' mental operations are slower, they process information less efficiently (Luo & Craik, 2008; Salthouse, 1996). (Refer to Table 1 above). Salthouse posits two mechanisms responsible for the relation between speed and cognition. "The *limited time mechanism* is assumed to operate because relevant cognitive operations are executed too slowly to be successfully completed in the available time, and the *simultaneity mechanism* is hypothesised to operate because slow processing reduces the amount of available information needed for higher level processing"

(Salthouse, 1996, p. 404). However, there are limitations associated with this model. Based on evidence from other studies, Luo and Craik (2008) suggest that allowing for extra processing time does not increase memory performance in older adults. In addition, age related differences have been identified on tasks that do not have a speed component e.g., free recall (Luo & Craik, 2008). This model is also unable to account for tasks that require different amounts of processing, suggesting other processes are involved (Luo & Craik, 2008).

Reduced processing resources.

The *reduced processing resources hypothesis* (Craik & Byrd, 1982) posits that attentional resources available for cognitive processing decreases with age. (Refer to Table 1 above). Attentional resources are conceptualised as a "mental energy" that enable cognitive tasks to be performed (Craik & Byrd, 1982). In addition, Craik and Rose (2012) argue that available mental energy is a metaphor for the constraints on resources that can be allocated to concurrent tasks. Based on this framework, it is postulated that a reduction in attentional resources affects the richness, extensiveness, and depth of processing at both encoding and retrieval (Craik & Byrd, 1982). However, another possibility is that rather than reduced resources, a decrease in performance may be attributed to less effective or efficient use of the available resources. It has been claimed that some of the differential age effects in memory (e.g., older adults performing better on recognition than free recall, remembering the general idea over specific detail) are as a consequence of less demand on "attentional resources".

However, Hasher and Zacks (1988) and Luo and Craik (2008) argue that the *reduced processing resources hypothesis* is vague in the operalisation of attentional resources. Although Salthouse (1991) proposed speed, working memory and attention as possible constructs, the exact nature of processing resources is still unclear. Further, the neural correlates of attentional resources are unclear (Luo & Craik, 2008). In addition, it is

speculated that the model is simplistic in suggesting that a general decline in attentional resources is able to explain the differential effects of decline across other cognitive domains.

Modular Perspective

Delaloye et al. (2009) and others e.g., Verhaeghen and Cerella (2002) have found what appears to be decline in specific cognitive abilities without accompanying generalised decline. In addition, researchers (e.g., Craik and Rose, 2012; Luo & Craik, 2008) argued that whilst there are substantial age related declines on some memory tasks, others show little evidence of decline at all. These findings challenge the notion that age related changes are generalised and instead suggest that specific sub-systems may decline independently.

Executive functioning decline.

The *executive functioning decline hypothesis/prefrontal cortex function theory* in which West (1996) extended on the work of Demster (1992), proposes that cognitive processes associated with the prefrontal cortex are more vulnerable to age related decline than those supported by other regions of the brain. (Refer to Table 1 above). As can be seen in Figure 2 below, executive functioning as the junction of several different subsystems may cause failure in what appears to be short-term memory and other cognitive processes. This provides some evidence of modularity. An alternative explanation is that modularity might actually be nothing more than an artifact of insensitive instrumentation in the detection of cognitive decline. It could be that cognitive measures are more sensitive in some domains than in others and hence differences in decline may be no more than differences in instrumentation. The purpose of this study was to investigate whether there is generalised degradation of overall cognitive function or whether decline is modular.

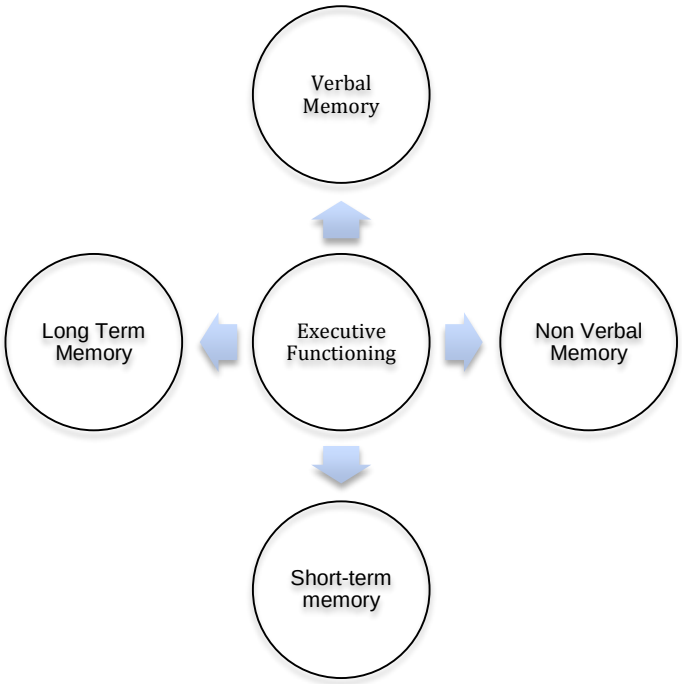

Figure 2. Visual Representation of Cognitive Subsystems

Cognitive Reserve: Buffers Against Age Related Cognitive Decline?

Regardless of the nature of age related cognitive decline, generalised or modular, other protective and risk factors have been identified. The *cognitive reserve hypothesis* proposes the idea of differential preservation in cognition and that those individuals who have higher levels of cognitive reserve (the brain's ability to actively cope and function after damage), are more likely to maintain higher levels of cognitive performance. Cognitive reserve mechanisms are active processes in response to neurobiological decline, that attempt to compensate for the inevitable loss of some connections by using alternative or redundant cognitive associations, making the brain less susceptible to disruption. It is thought that factors such as level of education/IQ/literacy and socioeconomic status (higher income/occupational attainment) may contribute to higher levels of cognitive reserve and hence delay the onset of disease (Steffener & Stern, 2012; Stern, 2009). There is also evidence that bi or multilingualism may serve as a protective factor, delaying the onset of

decline in cognitive functioning (Craik, Bialystok, & Freedman, 2010; Schweizer, Ware, Fischer, Craik, & Bialystok, 2012). Craik et al. (2010) found that those who were bilingual exhibited symptoms of decline later than monolingual individuals. Moreover, Schweizer et al. (2012) found whilst Alzheimer's disease associated neural atrophy was more pronounced in bilingual patients compared to monolingual patients, the groups did not differ on tasks assessing cognitive functioning. This may indicate bilingualism acts as a protective factor, delaying onset of cognitive decline. For example, a person who is multilingual may have more than one association for the word 'dog'. Therefore, if one pathway is damaged, they may still be able to retrieve the association through another, perhaps less direct route, unlike an individual who speaks one language that may only have one connection.

Recently, it has been suggested that the incidence of Alzheimer's disease is less than what would be expected using historical trends. It has been argued that there may be a protective factor occurring in more recent times that has decreased the rate of onset. Christensen et al. (2013) found that although individuals born later (1915) were two years older at initial testing, they still had superior performance on tests assessing cognitive functioning than those born earlier[3] (1905). The authors claim that the latter cohort benefits from more protective factors (e.g., intellectual stimulation), which may contribute to higher levels of cognitive performance. As the older populations used in the current thesis were born after 1915, we may expect to see a relative preservation in accuracy. However, there may also be an accompanying increase in latency due to the use of these redundant connections and consequently older individuals are likely to take longer in the retrieval of information.

Forms of Assessment

Neuropsychological testing is considered the 'gold standard' of diagnosis with technologies such as Positron Emission Tomography (PET) and Magnetic Resonance

[3] The authors adjusted for increase in education between 1905 to 1915 cohorts.

Imaging (MRI) being the most common technologies used. However, there is a question regarding the validity of the inferences drawn from using this type of equipment. For example, when a dead salmon was placed in an fMRI (functional Magnetic Resonance Imaging), the scan found evidence of brain activity, suggesting that it was thinking about the pictures that had been viewed (Bennett, Baird, Miller, & Wolford, 2009). In addition, the administration of the equipment is costly, time consuming, and impractical (Burnham et al., 2013; Roe et al., 2013; Zadikoff et al., 2008). In order to make the assessment of cognition less invasive, as well as more cost and time efficient, instruments (e.g., Mini Mental State Examination (Folstein et al., 1975) have been designed to provide an assessment of cognitive functioning. Refer to Table 2 below for a brief overview of measures used in assessing cognitive decline. Refer to Appendix A for a more detailed description of the measures.

Table 2

Measures used in the Assessment of Cognitive Decline

Instrument	Domains/s
Mini Mental State Examination (MMSE; Folstein, Folstein, & McHugh, 1975)	Attention or Calculation, Orientation, Registration, Recall, Language
Montreal Cognitive Assessment (MoCA; Nasreddine et al., 2005)	Executive Functioning, Visuospatial Abilities, Memory, Attention, Concentration, Language, Orientation
Clock Drawing Test (CDT; Goodglass & Kaplan, 1983)	Comprehension, Planning, Memory, Visuospatial Abilities, Motor Programming, Numerical Knowledge, Inhibition, Concentration and Frustration Tolerance
Mini Cog (Borson et al., 2003)	Memory, same domains as CDT
Florida Brief Memory Screen (FBMS; Loewenstein et al., 2009)	Memory
Cog-State (CogState.Com, 2010)	Attention, Processing Speed, Memory, Decision Making, Visual Tracking
7 Minute Screen (7MS; Solomon et al., 1998)	Orientation, Memory, Visuospatial abilities, Language, same domains as CDT
Kokmen Short Test of Mental Status (Kokmen et al., 1987)	Orientation, Attention, Learning, Calculation, Abstraction, Information, Construction, Recall
Memory Impairment Screen (MIS; Buschke et al., 1999)	Memory

Problems with Current Instrumentation

Whilst the domains of cognition likely to be impacted in mild cognitive impairment have been well identified in the literature, the instrumentation available lacks both sensitivity and specificity. These instruments, e.g. the Mini Mental State Examination (MMSE; Folstein et al., 1975) may be of some utility in the detection of dementia; however, they have been found not to have adequate sensitivity in detecting earlier stages of decline. Also, as these instruments measure across several domains, in general they fail to separate domains well. Moreover, they fail to assess other cognitive domains thought to be associated with mild cognitive impairment e.g., emotion recognition (Calder et al., 2003). Another criticism is that these instruments are administered manually; which increases measurement error and does not allow collection of latency of response, a key indicator in the detection of cognitive decline. More recent research (e.g., De Jager et al., 2009; Inoue et al., 2005) supports the use of computerised administration. Darby, Maruff, Collie, and McStephen (2002) suggested that computer administered tests are likely to be more sensitive in the detection of cognitive

decline than pen-and-pencil tasks. Therefore, in order to collect sensitive measures of both accuracy and latency to respond, computer-administered tests were used in the current study.

Aims of Research

The aims of the current thesis are to clarify both the nature and onset of cognitive decline. From the literature, it is unclear whether the aging process affects the entire brain, resulting in an overall generalised degradation of cognitive functioning. The alternate model is that decline affects the brain differentially, with some neurological structures declining faster than others. Therefore, a series of five studies was conducted assessing cognitive domains that are claimed to decline with age to investigate whether age related cognitive decline is generalised or modular. It is also unclear at what age the decline process may begin. Previously, it was thought that a loss of functioning might occur after the age of 65; however, there is some evidence that decline may begin as early as the second decade of life (Murre et al., 2013). Therefore, the current study also investigated cognitive performance in younger adults to determine whether there is evidence of incipient decline. The development of sensitive instrumentation in the detection of cognitive decline, along with deeper understanding of the nature and onset of cognitive decline may allow for more effective treatment or intervention pathways.

Chapter 2: Overall Discussion of Methodology and Research Design

The aims of the current thesis were to clarify both the nature and onset of cognitive decline. As previously mentioned, there is still some debate as to the mechanisms of age related decline. There is some evidence that organic processes may cause widespread damage to the brain (e.g., beta amyloid plaque damage), resulting in an overall *generalised decline.* An alternate view is that some neurological structures may appear to decline more rapidly than others, suggesting they are more vulnerable to decline or are differentially affected by the disease process. This could be described as a *modular decline.* If decline is found to be modular, such a result would have implications for differential diagnosis and perhaps eventually also for treatment. It is also unclear as to the age of onset. Previously, it was identified that decline may occur after the age of 65 but recent literature (e.g., Murre et al., 2013) has identified that decline may occur as early as the second decade in life. Therefore, the current study investigated cognitive performance in younger adults to assess whether decline occurs earlier than previously identified. The age of onset is also likely to have implications for treatment interventions. A series of five studies was conducted assessing cognitive domains that are claimed to decline with age.

Table 3 next gives a summary of the research questions and specific hypotheses; sampling and demographic characteristics of the participants; the instrumentation used to assess specific subdomains of cognitive functioning; and the analysis techniques used in each of the five studies.

Table 3

Overview of Studies 1 to 5 Detailing the Research Questions, Hypotheses, Sample, Instrumentation and Analyses Used

	Research questions	**Hypotheses**	**Sample**	**Instruments**	**Analyses**
Study 1	There is some evidence (e.g., Sorrel & Pennequin, 2008) of incipient decline of executive functioning and this was the focus of the first study. However, there is little evidence of age related decline in short-term memory (e.g., Luo & Craik, 2008). The aim of the current study was to assess whether age related decline occurs differentially or whether both processes are affected. If the processes were affected differentially, this would be indicative of modular decline and suggest the two systems operate independently. If both processes were found to decline, this would be more indicative of a generalised cognitive degradation.	Older adults would show more evidence of perseveration than younger adults. Older adults would have more difficulty inhibiting automatic response patterns than younger adults. There would be no age differences in short term memory.	Overall total sample *N* = 81 for Study 1. Total sample *N* = 75 with fifty females and 25 males. Sample aged 18-82 (*M* = 46.49, *SD* = 20.61). Forty-two participants nominated high school, 25 university, 7 T.A.F.E/college and 1 primary school as highest level of education obtained. Twenty-six participants were taking medication. *Young adults* (18-49) consisted of 35 participants aged 18-48 (*M* = 26.43, *SD* = 9.50) with 25 females and 10 males. Twenty participants nominated high school, 12 university and 3 T.A.F.E/college as highest level of education obtained. Two participants were taking medication. *Middle old adults* (50-64) consisted of 21 participants aged 50-64 (*M* = 58.30, *SD* = 4.23) with 15 females and 6 males. Eight participants nominated high school, 9 university and 3 T.A.F.E/college as highest level of education obtained. Ten participants were taking medication. *Older adults* (65 and above) consisted of 20 participants aged 66-82 (*M* = 69.80, *SD* = 4.05) with 10 females and 10 males.	Wisconsin Card Sorting Test to assess perseveration. Victoria Stroop Test to assess response inhibition. Digit span task to assess short term memory.	• Chi Square • One way between groups MANOVAs • One way between groups univariate ANOVAs

			Fourteen participants nominated high school, 4 university, 1 T.A.F.E/college and 1 primary school as highest level of education obtained. Fourteen participants were taking medication.		
Study 2	There is some evidence that emotion recognition declines with age (e.g., Ruffman et al., 2008). Therefore one of the aims of the study was to assess whether there was evidence of age related cognitive decline in recognition of emotional states. One possible mechanism of failure in emotion recognition is simple memory failure. There is some evidence of decline in memory for non-verbal material (e.g., Trahan et al., 1986) which might suggest that an older individual may have forgotten what a previously studied face looks like. An alternative account of failure in emotion recognition may lie in the use of verbal memory to encode emotional states. Consequently, a further aim of the current study was to assess whether changes in emotion recognition could be attributed to decline in memory processes. Further, the aim was to assess whether age related decline is generalised or modular. If decline were observed for only one memory process, this would provide evidence of dissociation in memory and also support a modular theory.	Older adults would have significantly poorer recognition of faces than younger adults on the emotion recognition task. Age related decline in emotion recognition would be accompanied by non-verbal memory decline rather than verbal memory decline.	Overall total *N* = 62 for Study 2. Total sample *N* = 62 with forty-eight females and 14 males. Sample aged 18-84 (*M* = 50.47, *SD* = 20.83). Forty-one participants nominated high school, 13 university, 6 T.A.F.E/college and 2 nominated primary school as highest level obtained. Twenty-eight participants were taking medication. *Young adults* (18-49) consisted of 21 participants aged 18-49 (*M* = 24.71, *SD* = 9.32) with 18 females and 3 males. Seventeen participants nominated high school and 4 university as highest level of education. One participant was taking medication. *Middle old adults* (50-64) consisted of 21 participants aged 50-64 (*M* = 57.29, *SD* = 4.60) with 18 females and 3 males. Nine participants nominated high school, 6 university, 5 T.A.F.E/college and 1 primary school as highest level of education obtained. Nine participants were taking medication. *Older adults* (65 and above) consisted of 20 participants aged 65 to 84 (*M* = 70.35, *SD* = 4.42) with 12 females and 8 males. Fifteen participants nominated high school, 3 university, 1 T.A.F.E/college and 1	Face recognition task to assess emotion recognition. Memory for faces task to assess non-verbal memory. Digit span task to assess verbal memory.	• Chi Square • One way between groups MANOVAs • One way between groups univariate ANOVAs

			primary school as highest level of education obtained. Eighteen participants were taking medication.		
Study 3	There is some evidence (e.g., Andersen & Ni, 2008) that visual processing declines with age. This may be reflected in the processing in the specific features of a face. Another possibility is that structures responsible for emotion processing change with age. This may be reflected in breakdown in the processing of emotional content. Consequently, these processes were investigated to assess whether age related decline is reflected in visual or emotional processing. Further, the aim was to assess whether age related decline is generalised or modular. If there is evidence of age related decline in visual processing but emotion processing remains intact, this would provide evidence of dissociation of process and further evidence of modular decline with increasing age. If both visual and emotion processing were found to decline, this would be more indicative of a generalised decline.	Older adults would have poorer performance than younger adults on the emotion recognition task. Older adults would be more likely to process faces holistically than younger adults. Older adults would be less accurate and slower to process valence stimuli.	Overall total *N* = 77 for Study 3. Total sample *N* = 73 with fifty two females and 21 males. Sample aged 19-82 (*M* = 51.44, *SD* = 19.70). Fifty participants nominated high school, 14 university, 6 T.A.F.E/college and 3 nominated high school as highest level of education obtained. Thirty-six participants were taking medication. *Young adults* (18-49) consisted of 26 participants aged 19 to 47 (*M* = 27.58, *SD* = 9.14) with 20 females and 6 males. Eighteen participants nominated high school, 5 university, 2 T.A.F.E/college and 1 nominated primary school as highest level of education obtained. Two participants were taking medication. *Middle old adults* (50-64) consisted of 24 participants aged 50 to 64 (*M* = 58.25, *SD* = 4.74) with 17 females and 7 males. Fifteen participants nominated high school, 5 university and 4 T.A.F.E/college as highest level of education obtained. Sixteen participants were taking medication. *Older adults* (65 and above) consisted of 23 participants aged 65 to 82 (*M* = 71.30, *SD* = 3.87) with 15 females and 8 males. Seventeen participants nominated high school, 4 university and 2 primary school	The facial recognition task used in study 2 was also used in the third study. A distorted facial recognition task based on the Margaret Thatcher illusion was used to assess visual processing. A valence-priming task was used to assess emotion processing.	• Chi square • Between groups factorial MANOVAs • One way between group MANOVAs • Mixed factorial MANOVAs • One way between groups univariate ANOVAs • Paired t-tests

			as highest level of education obtained. Eighteen participants were taking medication.		
Study 4	There is some evidence (e.g., Hudon et al., 2006) that as individuals age they remember the general specifics of stimuli rather than detail. Greater frequency of gist errors in aged populations has been claimed to be indicative of changes in memory. Consequently, one of the aims of the research was to assess whether older adults are more likely to make gist errors than younger adults. Further, an aim was to assess whether age related decline is modular or generalised. If there is age related decline for specific detail but memory for the general idea remains intact, this could be indicative of modular decline. However, memory for the general idea (gist) is more likely to be a consequence of storing generally. Therefore, if decline for memory of specific material is observed but memory for the general idea remains intact, this is likely to be more indicative of generalised decline. However, if decline for verbal material is observed but non-verbal remains intact, this would be indicative of dissociation of verbal and non-verbal representations and provide support for modular decline with increasing age.	Older adults would be more likely to make gist errors on both verbal and non-verbal tasks than younger adults.	Overall total *N* = 70 for Study 4. Total sample *N* = 66 with forty-nine females and 17 males. Sample aged 18-86 (*M* = 50.06, *SD* = 21.52). Forty-two participants nominated high school, 17 university, 5 T.A.F.E/college and 2 primary school as highest level of education obtained. Thirty-five participants were taking medication. *Young adults* (18-49) consisted of 24 participants aged 18 to 46 (*M* = 24.13, *SD* = 8.13) with 22 females and 2 males. Nineteen participants nominated high school, 3 university, 1 T.A.F.E/college and 1 primary school as highest level of education obtained. One participant was taking medication. *Middle old adults* (50-64) consisted of 22 participants aged 50 to 64 (*M* = 57.40, *SD* = 5.13) with 14 females and 6 males. Nine participants nominated university, 8 high school and 3 T.A.F.E/college as highest level of education obtained. Eleven participants were taking medication. *Older adults* (65 and above) consisted of 22 participants aged 65 to 86 (*M* = 71.68, *SD* = 5.33) with 13 females and 9 males. Fifteen nominated high school, 5 university, 1 T.A.F.E/college and 1 primary school as highest level of education obtained. Twenty one participants were taking medication.	Picture recognition task to assess non verbal gist Variation of the Deese/Roediger-McDermott (DRM) to assess non-verbal gist.	• One way between group MANOVAs

Study 5	From the literature (e.g., Spaan & Raajmakers, 2011) there is some indication that implicit memory may remain preserved. However, from the second and third studies there is some indication that memory for explicit material may decline with age. Consequently, an aim of the final study was to assess whether explicit and implicit memory processes decline with age. Further, the aim was to assess whether age related cognitive decline is generalised or modular. If decline in explicit memory is observed but implicit memory remains intact, this would provide evidence of dissociation in memory processing and provide further evidence of modular decline with increasing age. In addition, if decline were only observed for non-verbal implicit material, this would provide further support for modular decline. If decline were observed for both implicit and explicit memory, this would be more indicative of a generalised decline with increasing age.	Older adults would have poor performance than young adults on the explicit memory measure. There would be no age differences in implicit memory.	Overall total *N* = 70 for Study 5. Total sample *N* = 66 with forty-nine females and 17 males. Sample aged 18-86 (*M* = 50.27, *SD* = 21.06). Forty participants nominated high school, 17 university, 5 T.A.F.E/college and 4 primary school as highest level of education obtained. Thirty-six participants were taking medication. *Young adults* (18-49) consisted of 24 participants aged 18 to 46 (*M* = 25.04, *SD* = 8.2) with 22 females and 2 males. Eighteen participants nominated high school, 3 university and 3 primary school as highest level of education obtained. One participant was taking medication. *Middle old adults* (50-64) consisted of 21 participants aged 50 to 64 (*M* = 57.38, *SD* = 5.00) with 15 females and 6 males. Nine participants nominated university, 8 high school and 4 T.A.F.E/college as highest level of education obtained. Nine participants were taking medication. *Older adults* (65 and above) consisted of 21 participants aged 65 to 86 (*M* = 72.00, *SD* = 5.24) with 12 females and 9 males. Fourteen nominated high school, 5 university, 1 T.A.F.E/college and 1 primary school as highest level of education obtained. Twenty participants were taking medication.	Shum Visual Learning Test to assess non-verbal implicit memory. Stem completion task to assess verbal implicit memory. Digit span task to assess explicit memory.	• Mixed factorial MANOVA's • Correlational analyses • One way between group univariate ANOVAs

Sampling

The majority of the individuals that comprised the young adult sample were recruited through a private university in South-Eastern Queensland and received course credit for participation in the research. Participants in the older adult cohorts were recruited from fitness centres, independent living retirement villages and through word of mouth. Healthy older adults were required for the studies and operationalised as having no known diagnosed characteristics of Alzheimer's disease or other cognitive deficit, were independent living, and were able to take care of their own day-to-day needs. Initial screening checks were conducted on the data and atypical outliers were removed from the final analysis, including in all age cohorts. Although outliers in the older adult cohorts could provide some indication of cognitive decline, these outliers could also results from practice effects, lack of understanding of the task or lack of motivation. Participants were also excluded from the research if they were taking anti-psychotic or anti-epileptic medication. Older adults were still able to participate in the research if they were taking medication for blood pressure, cholesterol, diabetes or vascular problems. In this age group, taking medication is common. In addition, people who are regulated with medication are less likely to show cognitive deficits than those who are undiagnosed. Taking medication could potentially mask cognitive decline. However, individuals who were taking medication for depression were included in the research. Only 10 participants over the five studies were in this category with the majority of those on medication for blood pressure, cholesterol, diabetes or vascular issues.

Each of studies one to four used different cohorts of individuals and was conducted independently. The fifth study used the same individuals as study four and was conducted in the same testing session. Approximately 2 young adults, 6 middle old and 5 older adults participated in both studies one and two; 2 young adults, 8 middle old and 7 old participated

in both studies two and three; 2 young, 4 middle old and 5 older adults participated in both studies three and four. One young adult and one middle old adult completed all studies.

Limitations of the Sample

A purposive sampling technique was used. Although purposive sampling is not as representative as stratified random sampling and is not representative of the population, this technique is useful in gathering participants that share particular characteristics (Babbie, 2007). In this research, the characteristic of interest was 'independent living healthy older adults'. Due to the difficulties in obtaining participants with these specific characteristics via stratified random sampling, a random sampling technique could not be used. Consequently, the population used in the current research may not be representative of the population. Parametric statistics such as ANOVA were used to analyse the data. ANOVA is robust to minor violations of assumptions. Screening checks were conducted prior to analysis and it was decided that the data was suitable for the analyses proposed.

As individuals were selected on the basis of non-random sampling, there is the potential for sampling bias to affect the findings of the research. Consequently, this may limit generalisability of the findings. The smaller samples used in the research might also limit the generalisability to a wider population. It was also identified that females were over represented in the current thesis. Again, this may limit generalisability of the results obtained as males may have performed differently.

Critique of Instrumentation

The instrumentation currently used in the detection of cognitive decline lacks both sensitivity and specificity. Although many of the instruments e.g., the Mini Mental State Examination (MMSE; Folstein et al., 1975), 7 Minute Memory Screen (Solomon et al., 1998), The Kokmen Short Test of Mental Status (Kokmen et al., 1987), and the Memory Impairment Screen (MIS; Buscke et al., 1999) have shown some utility in the detection of

Alzheimer's disease, they have been found to lack adequate sensitivity or have not been validated in detection of the earlier stages of decline. As mentioned in Appendix A, the MMSE (Folstein et al., 1975) has been considered the gold standard of cognitive assessment for physicians. However, the instrument has been criticised as lacking sensitivity and predictive value, as being influenced by education level and as having a bias towards verbal items. Moreover, it has been found to have limited utility in differentiating dementia from non-dementia, suggesting limited diagnostic utility.

In addition, as these instruments measure across several domains, in general they fail to separate domains well. Moreover, they fail to assess other cognitive domains thought to be associated with mild cognitive impairment e.g., emotion recognition (Calder et al., 2003). Another criticism is that these instruments are administered manually; which increases measurement error and does not allow collection of latency of response, a key indicator in the detection of cognitive decline. More recent research (e.g., De Jager et al., 2009; Inoue et al., 2005) supports the use of computerised administration. Darby et al. (2002) suggested that computer administered tests are likely to be more sensitive in the detection of cognitive decline than pen-and-pencil tasks. Therefore, in order to collect sensitive measures of both accuracy and latency to respond, computer-administered tests were used in the current study. Computerised measures of latency ensure that reaction times collected are accurate to the millisecond.

Validity and Reliability

To reduce measurement error, participants were provided with consistent instructions for each of the tests. Participants were also required to indicate that they understood the nature of the task prior to the commencement of each test. Reaction time was measured on the computer to ensure precise timing to the millisecond rather than using a stopwatch that may cause inaccuracies due to lag in human processing.

As addressed in the final chapter, due to a lack of dedicated lab space at the institution where the study was conducted, the participants were tested in a variety of environments including offices and homes. Having all participants tested in the same lab space may have produced more reliable results and ensured that environmental factors such as noise were controlled for. However, it is also possible that there may have been a performance decrement associated with context, as participants would be unfamiliar with a lab setting. Therefore, by testing people in their own environment, this is likely to have increased ecological validity.

Chapter 3

Study 1: Assessing Differences in Executive Functioning and Short Term Memory for Young, Middle and Older Adults

Executive functioning has been postulated to encompass a variety of mental operations including shifting, abstract thinking, updating, planning, categorization, problem solving, decision making, self-monitoring, organization and inhibition (Boller & Grafman, 2002; Miyake et al., 2000). Baddeley's model of working memory refers to executive functioning as the central executive, which is thought to coordinate attentional activities and coordinate responses. Further, Baddeley posits that the central executive allocates resources to cognitive tasks. Miyake et al. (2000) conceptualised executive functioning as "general purpose control mechanisms that modulate the operation of various cognitive sub-processes and thereby regulate the dynamics of human cognition" (p. 50).

Shifting is considered the ability to switch between multiple tasks or mental sets (Miyake, 2000). Researchers (e.g., Sorel & Pennequin, 2008) have found that the ability to shift declines with age and hence was considered as a target for detection in the current study. Berg (1948) using the Wisconsin Card Sorting Test found that the older participants (sample aged 58-73) perseverated in their original responding strategy and therefore were unable to complete any categories on the task. Sorel and Pennequin (2008) also assessed shifting using the Plus-Minus Task as part of their research. The task involved administration of three lists of random numbers that ranged from 10 to 99. The participant was required to add three to each number in the first task, subtract three from the number in the second task, and alternate between adding and subtracting in the final task. Shifting costs were calculated by the difference in the average time taken to complete the first two lists and completion time of the

final list. Sorrel and Pennequin (2008) found that the oldest cohort had a significantly higher cost of shifting than the two younger cohorts. Delaloye et al. (2009) using global-local and number-letter measures found when education had been controlled, that older adults had higher shifting costs on the global-local measure in comparison to the three younger cohorts. The preceding argument shows evidence that the ability to *shift* declines with age. This might suggest shifting is potentially a sensitive measure of cognitive decline, if evidence of change in shifting is found in healthy populations with age.

Response inhibition is the ability to disengage from extraneous thoughts or associations that may plague an individual when completing a task. Researchers (e.g., Belleville et al., 2007; Troyer et al., 2006) have found increasing age may affect the ability to disengage from automatic response patterns and hence was considered as a potential target for the current study. Hasher, Zacks, and May (1999) also indicate that inhibitory mechanisms become less efficient with age.

Hasher et al. (1999) posited that inhibitory mechanisms limit the amount of irrelevant information in working memory. In addition, inhibitory mechanisms limit the amount of activated but irrelevant information from entering working memory. Thus, inhibition reduces the amount of cross-talk from irrelevant representations and enables attending to relevant information. Inhibition also controls active information in working memory by suppressing the activation of irrelevant information. Moreover, inhibitory mechanisms prevent more prominent information from seizing control so other less relevant responses can be considered.

As a consequence of inefficient inhibitory mechanisms, an older individual is likely to have richer stores or more mental clutter due to the amount of irrelevant information in memory. Consequently, they are forced to rely on general information or information that is retrieved easily. This is similar to the gist work discussed in a later study ahead (Chapter 5).

Based on the results of other research Hasher et al. (1999, p. 663) also suggest "... people with poor inhibitory control may also search more pathways during retrieval". Again, this is likely to be due to the cluttered network that an individual needs to search to find information; consequently older adults could be expected to have slower retrieval. Refer to Figure 3 for a diagrammatical representation of Hasher et al.'s model.

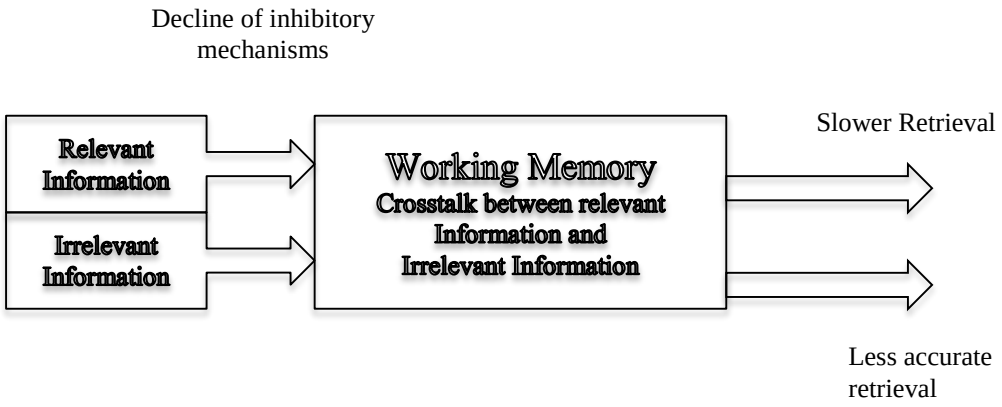

Figure 3. Visual Representation of Older Adults Inhibitory Mechanisms

If inhibitory mechanisms decline with age, then this may also provide a sensitive measure of cognitive decline, as they appear to exert a powerful effect even in healthy populations. The Stroop effect is thought to capture this process, as it requires participants to inhibit their automatic response and choose between two conflicting types of information. On this task, coloured words are presented that are semantically incongruent with their colour name (e.g., the word green presented in the colour red). An individual is required to *inhibit* the automatic response of reading the word and engage in the more effortful task of identifying the colour name. Therefore, if older adults are found to take longer on this condition, this could be indicative that older adults have deficit in response inhibition.

Crawford et al. (2007) using the Stroop Test in a healthy population, found that the amount of interference increased with age. Sorel and Pennequin (2008) using the Stroop Test

found middle and older adults had lower inhibition than young adults. In line with the framework discussed earlier, this is indicative that older adults have difficulty with inhibiting irrelevant information. Gronholm-Nyman, Rinne, and Laine (2009) also using the Stroop Test found Alzheimer's disease participants took significantly longer on the semantically incongruent condition compared to mild cognitive impairment and healthy adult control cohorts.

Wylie et al. (2007) also assessed response inhibition using an arrow version of a flanker task[4] in a sample of individuals with mild cognitive impairment and healthy controls. Wylie et al. (2007) found that participants with mild cognitive impairment demonstrated a higher reaction time than the control group when responding to a conflicting stimulus that was surrounded by distracters. A surprising aspect of the study was the lack of a suitable age comparison group. Therefore, it is difficult to establish whether older adults have decline of inhibitory mechanisms in comparison to younger cohorts.

As mentioned in the previous chapter, there is some evidence (e.g., Crawford et al., 2007; Delaloye et al., 2009) that certain areas of executive functioning may be more vulnerable to age related decline than others. If this were true, then this might suggest that rather than aging causing generalised degradation to all systems, it may be evident in particular systems before others, consistent with the modular decline model of aging. Crawford et al. (2007) examined executive functioning but found that performance on Verbal Fluency, Cognitive Estimates and Use for Common Objects did not decline with age. Delaloye et al. (2009) also found once controlling for education, that the global-local shifting and cube-updating task were the only executive functioning tasks strongly associated with an age related decline. In addition, Verhaeghen and Cerella (2002) through a review of five meta-analyses concluded that age related deficits were not found in local task switching or

[4] Another form of conflict task requiring inhibition of an incongruent response

selective attention, but emerged in dual task performance and shifting. This may also suggest that aging affects the brain differentially, rather than causing an overall general degradation of cognitive functioning.

Short Term Memory

Unlike executive functioning, there is some evidence that temporary storage of information in memory may remain invariant with age. Luo and Craik (2008) have differentiated short-term memory (referred to as working memory by the authors) into two processes: Primary memory, which involves the simple storage of information and true working memory, which involves both manipulation and storage of information. Baddeley (2012) also differentiates the two processes but refers to them as short-term memory and working memory respectively.

It has been argued that tasks requiring active processing are more likely to show age differences than those involving the simple maintenance of information in temporary storage (Luo & Craik, 2008; Nilsson, 2003). Traykov et al. (2007) as part of their research assessed short term memory using the digit span forward task from the Wechsler Adult Intelligence Scale (WAIS) and found equivalent performance in mild cognitively impaired participants and healthy older controls. Gronholm-Nyman et al. (2009) as part of their study also used digit span forward with mild cognitive impairment participants, Alzheimer's disease participants and healthy older controls. Gronholm-Nyman et al. (2009) found that there was no difference between groups, albeit the Alzheimer's disease participants having the lowest recall. These results support the idea that maintenance of information in short term memory shows little decline, even in diseased individuals. In the current study executive functioning and short-term memory were dissociated to assess whether decline occurs in one subsystem and not the other, or if both processes are affected.

Aims of Research

From the research (e.g., Sorrel & Pennequin, 2008) there is evidence of age related decline in executive functioning. In particular, there is some indication that the ability to shift from one problem solution to another declines with age. Therefore, it was expected that older adults would show more evidence of perseveration[5] than younger cohorts. There is also some indication from the literature (e.g., Crawford et al., 2007) that older adults have difficulty inhibiting automatic response patterns. Therefore, it was also expected that older adults would take longer to name the colour of the words on the semantically incongruent condition of the Stroop Test than younger adults. As Gronholm-Nyman et al. (2003) and others have found that older adults do not show decrement on tasks involving the simple maintenance of information in memory; no age differences were anticipated on the digit span task.

Using a dissociative paradigm, it was investigated whether decline occurs differentially or whether both processes are affected. If decline in executive functioning is observed but short-term memory remains intact, this would be indicative of modular decline with increasing age and suggest that the two systems operate independently. However, if both processes decline, this would be indicative of a generalised decline and suggest an overall degradation of cognitive function.

Method

Participants

A sample of 81 participants was recruited from South-Eastern Queensland to participate in the study. A purposive sampling technique was used. Although purposive sampling is not as effective as stratified random sampling and is not representative of the population, this technique is useful in gathering participants that share particular

[5] Tendency to stick to same responding strategy

characteristics (Babbie, 2007). In this research, the particular characteristic of interest was independent living healthy older adults. The participants that comprised the young old sample were first year psychology students from a university that received course credit for participation in the research. The other participants were recruited from the local community. Screening of the data lead to the final sample of 75 comprising 50 females (66.7%) and 25 males (33.3%). The age of the participants ranged from 18 to 82 years (M = 46.49, SD = 20.61). Forty-two participants (56.0%) nominated high school, 25 (33.3%) nominated university, 7 (9.3%) nominated T.A.F.E/college and 1 (1.3%) nominated primary school as highest level of education obtained. For the entire sample, 26 participants (34.7%) were taking medication for illnesses e.g., high blood pressure, high cholesterol, diabetes, depression, vascular problems and 49 (65.3%) were not taking medication. Chi-square analysis was also conducted to assess whether there was a difference in medical status by gender. However, this was not significant (χ^2 (1, n = 75) = .03, p = .864). Refer to Table 4 below.

Table 4

Cross-Tabulation of Medical Status x Gender

Gender	Medical Status	
	Taking medication	Were not taking medication
Males	9 (12.0%)	17 (22.7%)
Females	16 (21.3%)	33 (44.0%)

The participants were divided into three groups depending on age. The younger adults group (18-49) consisted of 35 participants with ages ranging from 18 to 48 (*M* = 26.43, *SD* = 9.50) with 25 (71.4%) females and 10 (28.6%) males. From the sample, 20 (57.1%) participants nominated high school, 12 (34.3%) university and 3 (8.6%) nominated T.A.F.E. or College as the highest level education obtained. Two of the participants (5.7%) were taking medication for illnesses e.g., high blood pressure, high cholesterol, diabetes, depression, vascular problems. Thirty-three (94.3%) participants were not taking medication.

The middle adults group (50 to 64) consisted of 21 participants with ages ranging from 51 to 64 (*M* = 58.30, *SD* = 4.23) with 15 (75.0%) females and 6 (25.0%) males. From the sample, 8 participants (40.0%) nominated high school, 9 (45.0%) university and 3 (15.0%) T.A.F.E/College as highest level of education obtained. Ten (50.0%) of the participants were taking medication for illnesses e.g., high blood pressure, high cholesterol, diabetes, depression, vascular problems. Ten (50.0%) participants were not taking medication.

The older adults group (65 and above) consisted of 20 participants with ages ranging from 66 to 82 (*M* = 69.80, *SD* = 4.05) with 10 (50.0%) females and 10 (50.0%) males. From the sample, 14 (70.0%) nominated high school, 4 (20.0%) university, 1 (5.0%)

T.A.F.E/College and 1 (5.0%) nominated primary school as highest level of education obtained. Fourteen (70.0%) of the participants were taking medication for illnesses e.g., high blood pressure, high cholesterol, diabetes, depression, vascular problems. Six (30.0%) participants were not taking medication.

Chi-square analysis was also conducted to assess whether there was a difference in medical status by age and was found to be significant ($\chi^2(2, n = 75) = 26.05, p < .001$). Refer to Table 5 below.

Table 5

Cross-Tabulation of Medical Status x Gender

	Medical Status	
Age	Taking medication	Were not taking medication
Young Old	2 (2.7%)	33 (44.0%)
Middle Old	10 (13.3%)	10 (13.3%)
Older Adults	14 (18.7%)	6 (8.0%)

Instruments

Executive functioning.

The two measures selected for the current study assess different aspects of executive functioning and consequently help differentiate the areas of executive functioning associated with age related cognitive decline.

Wisconsin card sorting test. To assess executive functioning, the Wisconsin Card Sorting Test was used. The Wisconsin Card Sorting Test provides a measure of cognitive flexibility, as well as the ability to shift mental set in situations that are constantly changing

(Berg, 1948; Heaton, Chelune, Talley, Kay, & Kurtis, 1993). It has been claimed that the instrument can be used with participants aged between 6.5 and 89 years (Heaton et al., 1993). The instrument has been claimed to have adequate reliability and has been found to be sensitive to aging (Heaton et al., 1993; Lezak, 2012). The original Berg Wisconsin Card Sorting Test was administered manually, however, for a more accurate depiction of speed and accuracy, a computerised version of the task was used from the PEBL test battery (version 0.4). The computerised version of the instrument provides 10 objective scores (e.g. total errors, categories and perseverative error responses) designed to provide a comprehensive depiction of an individual's executive functioning.

The task involves the administration of 128 response cards that have a varied number of stars, crosses, triangles, or circles that are coloured in red, yellow, blue, or green. On each trial, the participant is presented four reference cards from left to right: One red triangle, two green stars, three yellow crosses and four blue circles. They are then required to sort each of the 128 response cards into one of the four references card piles based on *design form* (triangle, star, cross or circle) *colour* (red, green, yellow or blue) or *number of items* (one, two, three, four). The individual is provided feedback after each trial as to whether they are sorting based on the current rule correctly. The task is self-paced, requiring participants to respond as quickly as possible. In some instances the card might match more than one condition (e.g., a card with 4 yellow stars could be sorted into the 2 green star based on design form, the three yellow crosses based on number of items or into the 4 blue circles based on number of items) and the participant must then decide which sorting principle to follow. (Refer to Figure 4 below). After five successful trials, the rule is changed and the participant is required to sort the card based on the new rule that is being applied.

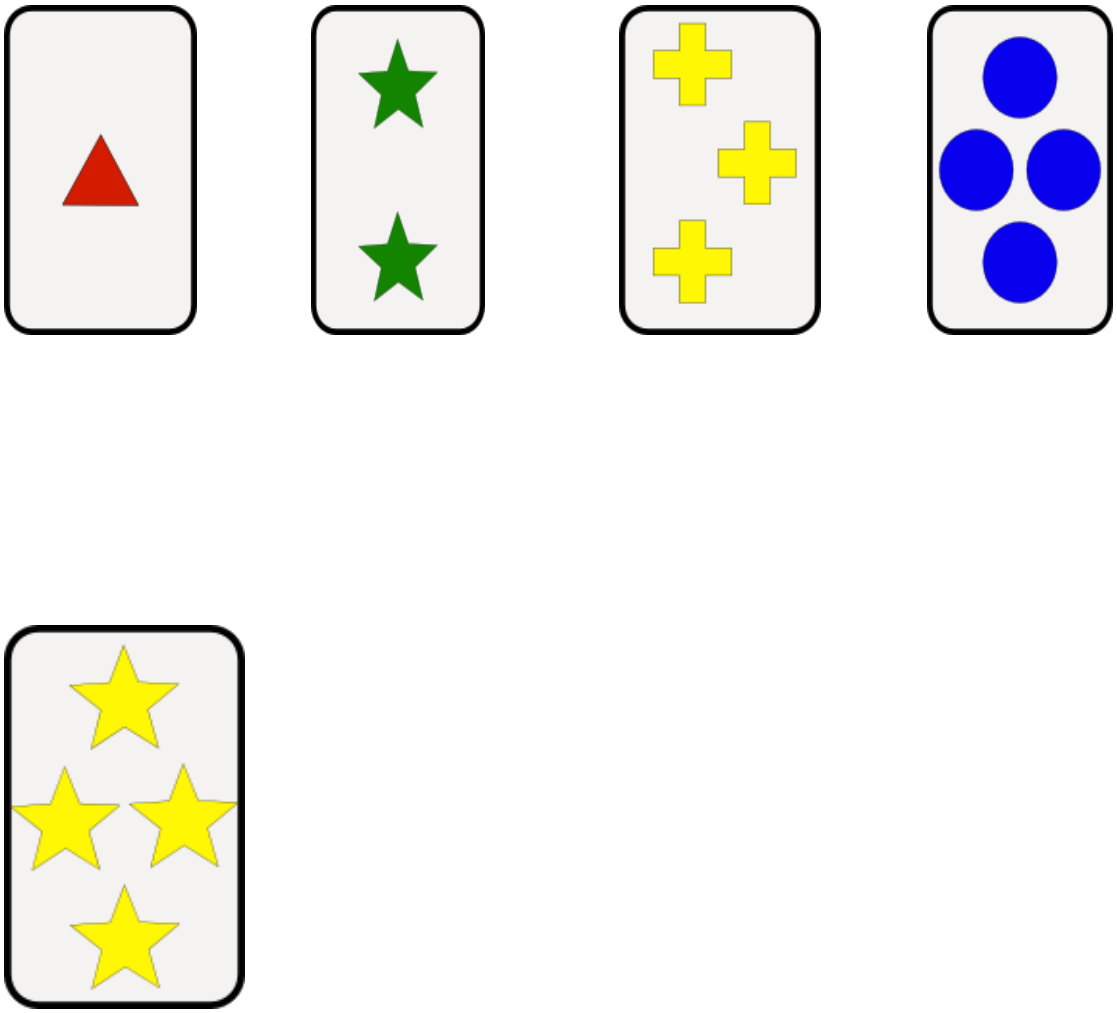

Figure 4. Example of Trial from Wisconsin Card Sorting Test

Victoria stroop test. To assess executive functioning, the Victoria Stroop Test was used. It has been claimed that the instrument can be used with people aged between 18 and 94 years (Strauss et al., 2006). The Victoria Stroop Test provides a sensitive depiction of cognitive changes such as response inhibition, which are thought to occur with age (Troyer et al., 2006). The instrument has been claimed to have adequate psychometric properties including sensitivity to aging effects (Bayard et al., 2011). For ease of administration and to be able to accurately obtain latency data, a computerised version of the task was used in the current study.

The Victoria Stroop Test contains three conditions (Coloured Patches, Neutral and Semantically Incongruent) which each consist of 24 trials. The task is self-paced. The first condition contains patches that are coloured in red, green, blue or yellow. The neutral condition contains the words “when”, “hard”, and “over” which are presented in red, green, blue, or yellow. The words are designed to be neutral and not to provide semantic interference or “Stroop effect”. This condition was designed as a training condition in order to help examinees establish colour-naming abilities before the semantically incongruent condition (Troyer et al., 2006). The final condition contains words that are semantically incongruent with one another (e.g., the word blue presented in the colour green).

The interference effect or “stroop effect” is calculated by the extra time required to name the colours in the semantically incongruent condition compared to the time required to name the colours in the neutral condition (Strauss et al., 2006). Refer to Figure 5 below for example stimuli from the three conditions of the task.

Coloured Patches Condition

Neutral Condition

Semantically Incongruent Condition

Figure 5. Example Stimuli from the three Conditions of the Victoria Stroop Test

Digit span. To assess short-term memory, a digit span task was used which is designed to assess an individual’s ability to keep information in short-term memory storage. The stimuli for this task were sets of numerical digits. The lowest number presented was one

digit and the highest that could be reached was 15 digits. It was expected that healthy individuals would recall 7 +/-2 digits (Miller, 1994).

The task was formulated using a staircase method where once an estimate of response threshold was obtained; stimuli were never presented far from this threshold (Kantowitz et al., 2009). The first trial began with three digits presented and each ongoing presentation would subsequently increase depending on correct recall. The sequence of numbers would continue to increase if correct and drop back a digit if an incorrect sequence was recalled. The task would end either when the participant had reached maximum span performance or once 30 trials had been completed. The 30 trials ensured maximum span performance was obtained. An average of 5 trials for both accuracy and latency was taken to obtain span performance. The data was taken from trials 12-17 to reduce the potential of practice and fatigue effects which may have occurred during the start or end trials; thereby ensuring the most reliable measure of performance.

For each trial, the display time of the stimuli was 3000 ms to ensure sufficient encoding of the digits. A 2000 ms blank time was presented and then participants were provided 10,000 ms to recall each trial of digits. Once 10,000 ms had been reached, a timeout would occur and the next trial would be presented with one digit removed.

Experimental hardware. Each of the tasks was visually presented on a 15 inch Toshiba Satellite L300 laptop. The laptop had an AMD Athlon 64 X 2 Dual-Core 2.8 GHz Processor running Windows 7 with 4GB of ram. The screen resolution was 32 bit and set at 1024 x 768 pixels.

Procedure

A potential issue that can arise in memory testing is that performance can be decremented when people are in unfamiliar locations (Russo, Ward, Geurts, & Scheres, 1999). Therefore, middle and older adult participants were tested in situ (home or office

locations) in order to obtain the most accurate performance. Although younger participants were tested at university, this is a familiar environment and therefore performance is unlikely to be decremented. For older people, a university environment could be daunting and therefore some of the differences in test performance might just be a function of the site of testing. The second argument is that older people may be less mobile and subsequently less inclined to travel than younger participants.

Participants were seated in front of the laptop and presented each of the tasks in the following order: The Wisconsin Card Sorting Test, Digit Span and the Victoria Stroop Test. The tasks were not counterbalanced as the Wisconsin Card Sorting Test is considered the most demanding and therefore to reduce the potential for fatigue effects was presented first. Participants were instructed to read the instructions on the screen and indicate that they understood prior to the commencement of each task.

Wisconsin Card Sorting Test. Prior to the commencement of the task, the following instructions were presented on the laptop screen:

'You are about to take part in an experiment in which you need to categorise cards based on pictures appearing on them. To begin, you will see four piles (press any key to see the four piles.'

On the next screen, four cards were presented: A red triangle with the number 1 underneath, two green stars with the number 2 underneath, three yellow crosses with the number 3 underneath, and four blue circles with the number 4 underneath. Beneath these cards the following instructions were presented:

'Each pile has a different number, colour, and shape. You will see a series of cards and need to determine which pile each belongs to. Press the 1-4 keys along the top of the keyboard to determine the pile each new card belongs in. The correct answer depends upon a

rule, but you will not know what the rule is. But, we will tell you on each trial whether or not you were correct. Press any key to continue'.

'Finally, the rule may change during the task, so when it does, you should figure out what the rule is as quickly as possible and change with it. Press any key to begin'.

Victoria Stroop Test. Prior to the commencement of the coloured patches condition, the following instructions were presented on the laptop screen:

"In this test we are investigating how long it takes to process colour information. Your job is to name the colour of the dot shown in the center of the screen as quickly as possible. Name the colour by pressing the R, G, B, or Y key on the keyboard as quickly as possible. R indicates the dot was red, G indicates the dot was green, B indicates the dot was blue, and Y indicates the dot was yellow."

Prior to the neutral condition, the following instructions were presented on the laptop screen:

"In this test we are still investigating how long it takes to process colour information. Your job is to name the colour of the word shown in the center of the screen as quickly as possible. Name the colour by pressing the R, G, B, or Y key on the keyboard as quickly as possible. R indicates the word was red, G indicates the word was green, B indicates the word was blue, and Y indicates the word was yellow."

Prior to the semantically incongruent condition, the following instructions were presented on the laptop screen:

"In this test we are still investigating how long it takes to process colour information. Your job is to name the colour of the word shown in the center of the screen as quickly as possible. Name the colour by pressing the R, G, B, or Y key on the keyboard as quickly as possible. R indicates the word was red, G indicates that the word was green, B indicates the word was blue, and Y indicates the word was yellow".

Digit span. Prior to the commencement of the task, the following instructions were presented on the laptop screen:

'In this experiment we will investigate your short-term memory. You will be presented with "sets" of digits. Each new list is called a "repetition". Your task is to remember as many of the digits as you can in the sequence. At the end of each set you will be asked to type in the digits or letters separated by a space into a text box. If you recall the sequence in correct order the number of digits will increase by one. If you make an error the number of digits will be decreased by one. The experiment will end when you have completed 30 trials, or have exhibited stable recall'.

Design

Executive functioning.

Wisconsin card sorting test. A between subjects design was used. The independent variable was *Age* (Young Old (18-49), Middle Old (50-64), and Older Adults (65 and above)). The dependent variables were *Error* (Perseverative Errors, Non Preservative Errors, Total Errors and Unique Errors), *Responses* (Correct Responses and Perseverative Responses), *Trials* (Number of Trials and Trials to Complete First Category), *Categories Completed*, and *Perseverative Runs.*

Perseverative Errors are the number of repeated errors made despite feedback that the response is incorrect. *Non-Perseverative Errors* are the number of errors made but not ones that are made to a single incorrect sorting principle. *Total Errors* are the number of sorting errors made throughout the task. *Unique Errors* are the number of matches that are not based on any of the three sorting principles (colour, form, number). *Correct Responses* are the number of correct responses obtained on the test. *Perseverative Responses* are the number of responses made in which the participant persists in responding to a stimulus that is incorrect.

Number of Trials are the number of trials that was administered. *Trials to Complete First Category* are the number of trials taken to successfully complete sorting according to the first rule. *Categories Completed* is the number of sequences (10 consecutive correct matches) completed throughout the task. *Perseverative Runs* are the number of times the individuals engaged in a particular response strategy.

Victoria stroop test. A between subjects design was used. The independent variable was *Age* (Young (18-49), Middle Old (50-64), and Older Adults (65 and above)). The dependent variable was *Latency* (Coloured Words and Semantically Incongruent Words).

Short-term memory.

Digit span. A between subjects design was used. The independent variable was *Age* (Young (18-49), Middle Old (50-64), and Older Adults (65 and above)). The dependent variables were *Mean Span* and *Mean Latency*.

Results

Preliminary Analysis

All data was screened and analysed using SPSS Version 21.0

Executive functioning.

Wisconsin card sorting test. Prior to analysis, the assumptions of MANOVA were tested. The assumption of sample size was met. Violations of normality were identified for all DVs using Kolmogorov-Smirnov ($p < .05$). However, MANOVA is robust to moderate violations of normality with larger sample sizes[6]. *Total Errors and Perseverative Errors* were highly correlated ($r > .7$). The literature notes that measures of the WCST are likely to be highly related and recommends using variables that are considered representative of specific WCST dimensions (Strauss et al., 2006). As the analysis is exploratory, all measures of the

[6] At least 20 in each cell (Tabachnick & Fidell, 2007)

WCST were included and results interpreted with caution. The data were linear. Five outliers were removed from the final analysis. Box's *M* was violated for *Responding* ($F(6, 47530) = 14.01$, $M = 87.94$, $p < .001$) and *Trials* ($F(6, 47940) = 5.95$, $M = 18.71$, $p < .001$). As Box's *M* was violated and sample sizes were unequal for *Age*, all *F* approximations are reported as *Pillai's criterion*. *Pillai's criterion* is more robust to violations of assumptions that other MANOVA metrics (Tabachnick & Fidell, 2007). No missing data was identified.

Victoria stroop test. Prior to analysis, the assumptions for MANOVA were tested. The assumption of sample size was met. Violations of normality for all DVs were identified using Kolmogorov-Smirnov ($p < .05$). However, MANOVA is robust to moderate levels of normality with larger sample sizes (Tabachnick & Fidell, 2007). The data were linear. One multivariate outlier was removed from the final analysis. The DVs of *Neutral Words* and *Coloured Patches* were approaching singular ($r > .9$). As we were more interested in performance on *Neutral Words, Coloured Patches* was removed from the final analysis. Box's *M* was violated ($F(6, 47530) = 6.87$, $M = 43.13$, $p < .001$). As Box's *M* was violated and sample sizes were unequal for *Age, F* approximations are reported as *Pillai's criterion*. No missing data was identified.

Short-term memory.

Digit span. Prior to running analyses, the assumptions for ANOVA were tested. Violations of normality for *Accuracy* were identified using Kolmogorov-Smirnov ($p < .05$). However, ANOVA is robust to violations of normality with larger sample sizes. Levene's Test indicated equal variances. One case was identified with missing data and a mean imputation was used.

Main Analysis

As there was an unbalanced design, *gender* and *education* were not included in the final analysis.

Executive functioning.

Wisconsin card sorting test. A ONEWAY between groups MANOVA (Multivariate Analysis of Variance) was conducted to assess the effect of *Age* (Young Old (18-49), Middle Old (50-64), and Older Adults (65 and above)) on *Error* (Perseverative Errors, Non-Perseverative Errors, Total Errors and Unique Errors) α was set at .05 apriori. As anticipated, there was a significant effect of *Age* on *Error* ($F_{pillai's}$ (8, 140) = 7.48, $p < .001$, partial η^2 = .30, power approaching 1). As the overall test of the weighted linear composite was significant, each of the dependent variables was then considered separately.

There was a significant effect of *Age* on *Perseverative Errors*, with middle old adults making significantly more perseverative errors than the young adults ($F(2, 72) = 4.51$, p = .014, partial η^2 = .11, power = .76). *Perseverative Errors* are the number of repeated errors made despite feedback that the response is incorrect. To investigate group differences between *Age*, a series of post hoc analyses were conducted using *Tukey's HSD* with $\alpha = .05$. Tukey's test was used, as it is a moderately conservative post hoc to control for familywise error rate over entire sets of pairwise comparisons (Keppel & Wickens, 2004). There was a significant difference between the young and middle old adults, with middle old adults making more perseverative errors than young adults (Refer to Table 6 below). However, there were no significant differences between young and older adults or middle and older adults (Refer to Table 6 below). As can be seen in Table 6 below, there is a high level of variance in perseverative errors for the older adult sample. This may be indicative of heterogeneity and that subgroups exist within the older adult cohort.

Table 6

Wisconsin Card Sorting Test (WCST) Error Rate by Age Group: Mean and Standard Deviations for Young Old, Middle Old, and Older Adults

	Age Group		
WCST domains	Young Old *M* *(sd)*	Middle Old *M* *(sd)*	Older Adults *M* *(sd)*
Perseverative Errors	16.80[b] *(5.72)*	25.35 *(11.25)*	24.20 *(17.90)*
Total Errors	27.09 [ab] *(9.64)*	42.25 [c] *(14.37)*	61.05 *(19.10)*
Non Perseverative Errors	10.23[a] *(6.04)*	16.90[c] *(7.83)*	36.85 *(27.99)*
Unique Errors	1.06 *(2.00)*	.45[c] *(.69)*	2.05 *(2.86)*

NB: a – Difference between young and older adults, b – Difference between young and middle old adults, c – Difference between middle and older adults

There was also a significant effect of *Age* on *Total Errors,* with evidence of monotonic decline for the number of total errors made ($F(2, 72) = 37.99$, $p < .001$, partial $\eta^2 = .51$, power approaching 1). *Total Errors* are the number of sorting errors made throughout the task. To investigate group differences between *Age,* a series of post hoc analyses were conducted using *Tukey's HSD* with $\alpha = .05$. There was a significant difference between young and older adults, with older adults making more total errors than young adults (Refer to Table 6 above). There was also a significant difference between young and middle old adults, with middle old adults making more total errors than the young adults (Refer to Table 6 above) In addition, there was a significant difference between middle old and older adults, with the older adults making more total errors than middle old adults (Refer to Table 6

above) The overall pattern was of monotonic decline with age with the most pronounced differences evident in the oldest group.

In addition, there was a significant effect of *Age* on *Non-Perseverative Errors*, with older adults making significantly more non-perseverative errors than young and middle old adults ($F(2, 72) = 19.06$, $p < .001$, partial $\eta^2 = .35$, power approaching 1). *Non-Perseverative Errors* are number of errors, but not ones that are made to a single incorrect sorting principle. To investigate group differences between *Age*, a series of post hoc analyses were conducted using *Tukey's HSD* with $\alpha = .05$. There was a significant difference between young and older adults, with older adults making more non-perseverative errors than young adults (Refer to Table 6 above). In addition, there was a significant difference between the middle and older adults, with older adults making more non-perseverative errors than middle old adults (Refer to Table 6 above). However, there was no significant difference between the young and middle old adults (Refer to Table 6 above). As can be seen in Table 6 above, there is again a high level of variance for non-perseverative errors for the older adults, suggesting heterogeneity within the cohort.

There was also a significant effect of *Age* on *Unique Errors*, with older adults making significantly more unique errors than the middle old adults ($F(2, 72) = 3.16$, $p = .048$, partial $\eta^2 = .08$, power = .59). *Unique Errors* are matches that are not based on any of the three sorting principles (colour, form, number). To investigate group differences between *Age*, a series of post hoc analyses were conducted using *Tukey's HSD* with $\alpha = .05$. There was a significant difference between middle and older adults, with the older adults making more unique errors (Refer to Table 6 above). However, there were no significant differences between young and middle old or young and older adults (Refer to Table 5 above).

Responding. A ONEWAY between groups MANOVA (Multivariate Analysis of Variance) was conducted to assess the effect of *Age* (Young Old (18-49), Middle Old (50-

64), and Older Adults (65 and above)) on *Responding* (Correct Responses and Perseverative Responding). α was set at .05 apriori. As anticipated, there was a significant effect *of Age* on *Responding* ($F_{pillai's}$ (4, 144) = 12.70, $p < .001$, partial $\eta^2 = .26$, power approaching 1). As the overall test of the weighted linear composite was significant, each of the dependent variables was then considered separately.

There was a significant effect of *Age* on *Correct Responses*, with evidence of monotonic decline for the number of correct responses made ($F(2, 72) = 36.24$, $p < .001$, partial $\eta^2 = .50$, power approaching 1). *Correct Responses* are the number of correct responses obtained on the test. To investigate group differences between *Age*, a series of post hoc analyses were conducted using *Tukey's HSD* with $\alpha = .05$. There was a significant difference between young and older adults, with older adults making fewer correct responses than young adults (Refer to Table 7 below). There was also a significant difference between young and middle old adults, with middle old making fewer correct responses than young adults (Refer to Table 7 below). In addition, there was a significant difference between middle old and older adults, with the older adults making fewer correct responses than the middle old adults (Refer to Table 7 below). The overall pattern was of monotonic decline[7] with age with the most pronounced differences evident in the oldest group.

[7] A monotonic decline is a generalised linear decline.

Table 7

Wisconsin Card Sorting Task (WCST) Responding by Age Group: Mean and Standard Deviations for Young Old, Middle Old, and Older Adults

	Age Group		
WCST domains	Young Old *M* *(sd)*	Middle Old *M* *(sd)*	Older Adults *M* *(sd)*
Correct Responses	98.40[ab] *(8.07)*	85.00[c] *(13.40)*	66.95 *(19.10)*
Perseverative Responses	42.89 *(6.30)*	46.40 *(12.53)*	39.75 *(25.83)*

NB: a – Difference between young and older adults, b – Difference between young and middle old adults, c – Difference between middle and older adults

However, there was no significant effect of *Age* on *Perseverative Responses* ($F(2, 72) = .94$, $p = .397$, partial $\eta^2 = .03$, power= .21). *Perseverative Responses* are the number of responses made in which the participant persists in responding to a stimulus that is incorrect. As can be seen in Table 7 above, there is a high level of variance in the older adult sample. Again, this is indicative of heterogeneity, suggesting that subgroups exist within the cohort.

Trials. A ONEWAY between groups MANOVA (Multivariate Analysis of Variance) was conducted to assess the effect of *Age* (Young Old (18-49), Middle Old (50-64), and Older Adults (65 and above)) on *Trials* (Number of Trials and Trials to Complete First Category) α was set at .05 apriori. As anticipated, there was a significant effect of *Age* on *Trials* ($F_{pillai's}(4, 144) = 3.22$, $p = .015$, partial $\eta^2 = .08$, power = .62). As the overall test of the weighted linear composite was significant, each of the dependent variables was then considered separately.

There was a significant effect of *Age* on *Trials to Complete First Category*, with middle old adults taking significantly more trials to complete the first category than young adults ($F(2, 72) = 4,28$, $p = .017$, partial $\eta^2 = .11$, power = .73) *Trials to Complete First*

Category are the number of trials taken to successfully complete sorting according to the first rule. To investigate group differences between *Age,* a series of post hoc analyses were conducted using *Tukey's HSD* with α = .05. There was a significant difference between young and middle old adults, with middle old adults taking the most trials to complete the first category than young adults (Refer to Table 8 below). However, there were no significant differences between young and older adults or middle and older adults (Refer to Table 8 below). Again, there is evidence of heterogeneity in the older adult sample (Refer to Table 8 below).

Table 8

Wisconsin Card Sorting Task (WCST) Trial Performance by Age Group: Mean and Standard Deviations for Young Old, Middle Old, and Older Adults

	Age Group		
WCST domains	Young Old *M* *(sd)*	Middle Old *M* *(sd)*	Older Adults *M* *(sd)*
Trials to Complete First Category	15.49 [a] *(6.86)*	27.00 *(14.54)*	19.60 *(21.24)*
Number of Trials	125.63 *(4.83)*	127.25 *(3.35)*	128.00 *(.000)*

NB: a – Difference between young and middle old adults

However, there was no significant effect of *Age* on *Number of Trials* ($F(2, 72) = 2.86$, $p = .064$, partial $\eta^2 = .07$, power = .54) (Refer to Table 8 above). *Number of Trials* is the number of trials that was administered in the task.

Categories. A ONEWAY between groups univariate ANOVA (Analysis of Variance) was run to compare assess the effect of *Age* (Young Old (18-49), Middle Old (50-64), and Older Adults (65+)) on *Categories. Categories* are the number of sequences (10 consecutive correct matches) completed throughout the task. α was set at .05 apriori. There was a

significant effect of *Age* on *Categories,* with evidence of monotonic decline for the number of categories completed ($F(2, 72) = 29.26$, $p < .001$, partial $\eta^2 = .44$, power approaching 1). To investigate group differences between *Age,* a series of post hoc analyses were conducted using *Tukey's HSD* with $\alpha = .05$. There was a significant difference between young and older adults, with older adults completing fewer categories than young adults (Refer to Table 9 below). There was also a significant difference between young old and middle old adults, with middle old completing fewer categories (Refer to Table 9 below). In addition, there was a significant difference between middle old and older adults, with older adults completing fewer categories (Refer to Table 9 below). The overall pattern was of monotonic decline with age with the most pronounced differences evident in the oldest group.

Table 9

Wisconsin Card Sorting Task (WCST) Number of Categories Completed by Age Group: Mean and Standard Deviations for Young Old, Middle Old, and Older Adults

	Age Group		
WCST domains	Young Old *M* *(sd)*	Middle Old *M* *(sd)*	Older Adults *M* *(sd)*
Categories Completed	6.80 [ab] *(1.88)*	4.75[c] *(2.40)*	2.45 *(1.93)*

NB: a – Difference between young and older adults, b – Difference between young and middle old adults, c – Difference between middle and older adults

Perseverative runs. A ONEWAY between groups univariate ANOVA (Analysis of Variance) was run to assess the effect of *Age* (Young Old (18-49), Middle Old (50-64), and Older Adults (65+)) on *Perseverative Runs. Perseverative Runs* are the number of times the individuals engaged in a particular response strategy. α was set at .05 apriori. There was no effect of *Age* on *Perseverative Runs* ($F(2, 72) = 1.24$, $p = .295$, partial $\eta^2 = .03$, power = .26) (Refer to Table 10 below). However, this might be explained by the high variance on

Perseverative Runs for the older adult cohort. Again, this is indicative of heterogeneity within the cohort.

Table 10

Wisconsin Card Sorting Task (WCST) Perseverative Runs by Age Group: Mean and Standard Deviations for Young Old, Middle Old, and Older Adults

	Age Group		
WCST domains	Young Old *M* *(sd)*	Middle Old *M* *(sd)*	Older Adults *M* *(sd)*
Perseverative Runs	2.24 *(2.10)*	2.64 *(1.94)*	4.56 *(9.82)*

A ONEWAY between groups MANOVA (Multivariate Analysis of Variance) was used to examine whether there was an effect of *Age* (Young Old (18-49), Middle Old (50-64), and Older Adults (65 and above)) on *Latency* (Neutral Words and Semantic Incongruent Words). α was set at .05 apriori. As anticipated, there was a significant difference of *Age* on *Latency* ($F_{pillai's}$ (4, 144) = 12.58, $p < .001$, partial $\eta^2 = .26$, power approaching 1). As the overall test of the weighted linear composite was significant, each of the dependent variables was then considered separately.

An unanticipated finding was a significant effect of *Age on Latency to Identify Neutral Words*, with evidence of monotonic decline for identifying the colour of the neutral words ($F(2, 72) = 33.12$, $p < .001$, partial $\eta^2 = .48$, power approaching 1). To investigate group differences between *Age,* a series of post hoc analyses were conducted using *Tukey's HSD* with $\alpha = .05$. Tukey's test was used, as it is a moderately conservative post hoc to control for familywise error rate over entire sets of pairwise comparisons (Keppel & Wickens, 2004). There was a significant difference between young and older adults, with older adults taking the longest to identify the colour of the neutral words (Refer to Table 11

below). There was also a significant difference between young adults and middle old adults, with middle older adults taking longest to identify the colour of the neutral words (Refer to Table 11 below). In addition, there was a significant difference between middle old and older adults, with older adults taking longest to identify the colour of the neutral words (Refer to Table 11 below). The overall pattern was of monotonic decline with age with the most pronounced differences evident in the oldest group.

Table 11

Mean Latency (ms) of Young Old, Middle Old, and Older Adults on Stroop Conditions

Conditions of Victoria Stroop	Young Old *M* *(sd)*	Middle Old *M* *(sd)*	Older Adults *M* *(sd)*
Neutral Words	736 [abc] (118)	964 (182)	1289 (377)
Semantically Incongruent Words	909 [ac] (330)	1101 (237)	1600 (528)

NB: a – Difference between young and older adults, b – Difference between young and middle old adults, c – Difference between middle and older adults

As expected, there was also a significant effect of *Age on Latency to Identify Semantically Incongruent Words*, with the older adults taking significantly longer to identify semantically incongruent words than the young and middle old adults ($F(2, 72) = 21.95$, $p < .001$, partial $\eta^2 = .38$, power approaching 1) To investigate group differences between *Age,* a series of post hoc analyses were conducted using *Tukey's HSD* with $\alpha = .05$. There was also a significant difference between young adults and older adults, with older adults taking longer to identify the colour of the semantically incongruent words (Refer to Table 11 above). In addition, there was a significant difference between middle and older adults, with older adults taking longer to identify the colour of the semantically incongruent words (Refer to Table 11

above). However, there was no significant difference between young old and middle old adults (Refer to Table 11 above).

Digit span. A ONEWAY between groups univarate ANOVA (Analysis of Variance) was run to assess the effect of *Age* (Young Old (18-49), Middle Old (50-64), and Older Adults (65+)) on *Mean Span.* α was set at .05 apriori. However, there was no significant effect of *Age* on *Mean Span* ($F(2, 72) = .27$, $p = .764$, partial $\eta^2 = .01$, power = .09) (Refer to Table 12 below).

Table 12

Mean Span and Latency (ms) Broken Down by Young Old, Middle Old, and Older Adults

	Age Group		
Span and Latency Variables	Young Old *M* *(sd)*	Middle Old *M* *(sd)*	Older Adults *M* *(sd)*
Mean Span	6.23 *(2.06)*	6.44 *(1.84)*	6.00 *(1.47)*
Mean Latency	6676[a] *(1260)*	7409 *(968)*	7610 *(1040)*

NB: a – Difference between younger and older adults

Latency. A ONEWAY between groups univariate ANOVA (Analysis of Variance) was also run to assess the effect of *Age* (Young Old (18-49), Middle Old (50-64), and Older Adults (65+)) on *Mean Latency*. α was set at .05 apriori. It was found that there was a significant effect of *Age* on *Mean Latency,* with older adults taking significantly longer to recall digits than young adults ($F(2, 72) = 5.21$, $p = .008$, partial $\eta^2 = .13$, power = .82). To investigate group differences between *Age,* a series of post hoc analyses were conducted using *Tukey's HSD* with $\alpha = .05$. Tukey's test was used, as it is a moderately conservative post hoc to control for familywise error rate over entire sets of pairwise comparisons (Keppel & Wickens, 2004). There was a significant difference between young and older adults, with

older adults taking longer to recall digits than young adults (Refer to Table 12 above). However, there were no significant differences between young and middle or middle and older adults (Refer to Table 12 above).

Exploratory Analysis

As there was a multimodal distribution and evidence of heterogeneity in the older adult sample, an exploratory analysis was run which further differentiated the two groups by functional performance. The older adult cohort was divided into low perseverative error older adults (less than 25) and high perseverative error older adults (>25).

A ONEWAY between groups univariate ANOVA (Analysis of Variance) was conducted to assess the effect of *Group* on *Perseverative Errors*. There was a significant effect of *Group* on *Perseverative Errors,* with the high perseverative error older adults making the most perseverative errors ($F(3, 71) = 22.06$, $p < .001$, partial $\eta^2 = .48$, power approaching 1). Post hoc analyses were conducted using *Tukey's HSD* with $\alpha = .05$. It was found that low perseverative older adults were significantly different from middle old and high perseverative error older adults, with fewer perseverative errors made. As anticipated, high perseverative error older adults made significantly more perseverative errors than young, middle, and low perseverative error older cohort. This suggests that a subsample within the older adults' cohort had a tendency to stick to a rigid, incorrect responding strategy. Consequently, they made more perseverative errors on the task.

A ONEWAY between groups univariate ANOVA (Analysis of Variance) was conducted to assess the effect of *Group* on *Non-Perseverative Errors*. There was again a significant effect of *Group* on *Non-Perseverative Errors*, with low perseverative error older adults making the most non-perseverative errors ($F(3, 71) = 30.14$, $p < .001$, partial $\eta^2 = .56$, power approaching 1). Post hoc analyses were conducted using *Tukey's HSD* with $\alpha = .05$. The low perseverative error older adults were also significantly different from all three

groups with significantly more non-perseverative errors made. The high perseverative error older adults were not significantly different from young or middle old adults. However, they were significantly different from low perseverative error older adults, with the low perseverative error older adults making significantly more non-perseverative errors.

A ONEWAY between groups univariate ANOVA (Analysis of Variance) was conducted to assess the effect of *Group* on *Total Errors.* There was also significant effect of *Group* on *Total Errors*, with low and high perseverative error older adults making the most total errors ($F(3, 71) = 25.48$, $p < .001$, partial $\eta^2 = .52$, power approaching 1). Post hoc analyses were conducted using *Tukey's HSD* with $\alpha = .05$. It was identified that the low perseverative error older adults made significantly more total errors than young and middle old adults. The high perseverative error older adults also made significantly more total errors than young and middle old adults. However, there was no difference between the two older cohorts. This suggests that both older cohorts had difficulty on the task. However, there was no effect of *Group* on *Unique Errors* ($F(3, 71) = 2.08$, $p = .110$, partial $\eta^2 = .08$, power = .59).

A ONEWAY between groups univariate ANOVA (Analysis of Variance) was conducted to assess the effect of *Group* on *Correct Responses*. There was a significant effect of *Group* on *Correct Responses*, with the low and high perseverative error older adults making significantly fewer correct responses than young and middle old adults ($F(3, 71) = 24.37$, $p < .001$, partial $\eta^2 = .51$, power approaching 1). Post hoc analyses were conducted using *Tukey's HSD* with $\alpha = .05$. It was identified that low perseverative error older adults made significantly fewer correct responses than the young and middle old adults. The high perseverative error older adults also made significantly fewer correct responses than the young and middle old adults. However, the two older cohorts were not significantly different from each other.

A ONEWAY between groups univariate ANOVA (Analysis of Variance) was conducted to assess the effect of *Group* on *Perseverative Responses*. It was identified that there was a significant effect of *Group* on *Perseverative Responses*, with high perseverative older adults making the most perseverative responses ($F(3, 71) = 22.47$, $p < .001$, partial $\eta^2 = .48$, power approaching 1). Post hoc analyses were conducted using *Tukey's HSD* with $\alpha = .05$. It was found that low perseverative error older adults made significantly fewer perseverative responses than young, middle old, and high perseverative older adults. The high perseverative error older adults were found to make significantly more perseverative responses than all cohorts.

A ONEWAY between groups univariate ANOVA (Analysis of Variance) was conducted to assess the effect of *Group* on *Number of Trials*. There was no significant effect of *Age* on *Number of Trials* ($F(3, 71) = 1.88$, $p = .140$, partial $\eta^2 = .07$, power = .47).

There was a significant effect of *Group* on *Trials to Complete First Category* ($F(3, 71) = 2.85$, $p = .043$, partial $\eta^2 = .11$, power = .66). However, no significant group differences were identified in the post hoc analysis.

A ONEWAY between groups univariate ANOVA (Analysis of Variance) was conducted to assess the effect of *Group* on *Categories*. There was also a significant effect of *Group* on *Categories*, with the low perseverative error older adults completing significantly fewer categories than young and middle old adults ($F(3, 71) = 19.98$, $p < .001$, partial $\eta^2 = .46$, power approaching 1). Post hoc analyses were conducted using *Tukey's HSD* with $\alpha = .05$. It was identified that the low perseverative error older adults completed fewer categories than the young and middle old adults. The high perseverative error older adults also completed significantly fewer categories than young adults. However, they were not significantly different from the middle old adults. In addition, the older cohorts were not significantly different from each other.

A ONEWAY between groups univariate ANOVA (Analysis of Variance) was conducted to assess the effect of *Group* on *Perseverative Runs.* There was a significant effect of *Group* on *Perseverative Runs,* with high perseverative error older adults making significantly more perseverative runs than young and low perseverative error older adults ($F(3, 71) = 3.68$, $p = .016$, partial $\eta^2 = .14$, power = .78). Post hoc analyses were conducted using *Tukey's HSD* with $\alpha = .05$. As expected, the high perseverative error older adults made significantly more perseverative runs than younger adults and low perseverative error older adults. The low perseverative error older adults did not make significantly more perseverative runs than young or middle old adults.

A ONEWAY between groups univariate ANOVA (Analysis of Variance) was conducted to assess the effect of *Group* on *Latency to Identify Neutral Words*. There was a significant effect of *Group* on *Latency to Identify Neutral Words*, with the low perseverative error older adults taking significantly longer to identify the colour of the neutral words than young and middle old adults ($F(3, 71) = 24.66$, $p < .001$, partial $\eta^2 = .51$, power approaching 1). Post hoc analyses were conducted using *Tukey's HSD* with $\alpha = .05$. The low perseverative error older adults took significantly longer to identify the colour of the neutral words than young and middle old adults. The high perseverative error older adults took significantly longer to identify the colour of the neutral words than young adults. However, the two older cohorts were not significantly different from each other.

A ONEWAY between groups univariate ANOVA (Analysis of Variance) was conducted to assess the effect of Group on *Latency to Identify Semantically Incongruent Words*. There was again a significant effect of *Group* on *Latency to Identify Semantically Incongruent Words,* with low and high perseverative error older adults taking the longest to identify the colour of the semantically incongruent words ($F(3, 71) = 14.34$, $p < .001$, partial $\eta^2 = .38$, power approaching 1). Post hoc analyses were conducted using *Tukey's HSD* with α

= .05. It was identified that low perseverative error older adults took significantly longer to identify the colour of the semantically incongruent words than young and middle old adults. In addition, the high perseverative error older adults took significantly longer to identify the colour of the semantically incongruent words than young and middle old adults. However, the two older cohorts were not significantly different from each other. As the two older cohorts were not significantly different from each other, this suggests that they both had difficulty in inhibiting automatic responses in the presence of conflicting choices, which resulted in longer latencies on the task.

A ONEWAY between groups univariate ANOVA (Analysis of Variance) was conducted to assess the effect of *Group* on *Mean Span.* There was no effect of *Group* on *Mean Span* ($F(3, 71) = .16$, $p = .924$, partial $\eta^2 = .08$, power = .08). A ONEWAY between groups univariate ANOVA (Analysis of Variance) was conducted to assess the effect of *Group* on *Mean Latency.* There was a significant effect of *Group* on *Mean Latency* ($F(3, 71) = 2.92$, $p = .040$, partial $\eta^2 = .11$, power = .67). However, no significant group differences were identified in the post-hoc analysis.

Additional Exploratory Analysis

As there was evidence of heterogeneity[8] and a multimodal distribution in the low perseverative responding older adult group, a further differentiation was made based on the number of non-perseverative errors made.

A ONEWAY between groups univariate ANOVA (Analysis of Variance) was conducted to assess the effect of *Group* on *Perseverative Errors.* It was identified that there was a significant effect of *Group* on *Perseverative Errors*, with low perseverative error, high non-perseverative error older adults making the fewest perseverative errors ($F(4, 70) = 22.16$,

[8] There is further evidence of a high level of variance in the low perseverative error older adults on non-perseverative errors, perseverative error responding, trials to completion and categories completed. Older individuals in the low perseverative error group who had a score of more than 45 were categorised into the low perseverative error, high nonperseverative error cohort. Older adults lower than 45 were categorized as the low perseverative error, low nonperseverative error cohort.

$p < .001$, partial $\eta^2 = .56$, power approaching 1). Post hoc analyses were conducted using *Tukey's HSD* with $\alpha = .05$. The low perseverative error, high non-perseverative older adults made significantly fewer perseverative errors than low perseverative error older adults, high perseverative error older adults, middle old, and younger adults. The low perseverative error older adults also made significantly fewer perseverative errors than the high perseverative error older adults. The low perseverative error, high non-perseverative error older adults were found not to make any perseverative errors on the task. To perseverate, an individual needs to remember the response strategy they are using and errors suggest they persist despite being told the strategy is incorrect.

A ONEWAY between groups univariate ANOVA (Analysis of Variance) was conducted to assess the effect of *Group* on *Non-Perseverative Errors*. There was a significant effect of *Group* on *Non-Perseverative Errors,* with low perseverative, high non-perseverative error older adults making the most non-perseverative errors ($F(4, 70) = 107.71$, $p < .001$, partial $\eta^2 = .86$, power approaching 1). Post hoc analyses were conducted using *Tukey's HSD* with $\alpha = .05$. As expected, low perseverative error, high non-perseverative error older adults made significantly more non-perseverative errors than low perseverative error older adults, high perseverative error older adults, middle old, and younger adults.

A ONEWAY between groups univariate ANOVA (Analysis of Variance) was conducted to assess the effect of *Group* on *Total Errors.* There was a significant effect of *Group* on *Total Errors,* with the low perseverative error, high non-perseverative error older adults making the most total errors ($F(4, 70) = 31.78$, $p < .001$, partial $\eta^2 = .65$, power approaching 1). Post hoc analyses were conducted using *Tukey's HSD* with $\alpha = .05$. It was identified that low perseverative error, high non-perseverative error older adults made significantly more total errors than low perseverative error older adults, high perseverative error older adults, middle old, and young adults. From the high number of total errors made,

there is a strong indication that low perseverative error, high non-perseverative error older adults had difficulty on the task. A ONEWAY between groups univariate ANOVA (Analysis of Variance) was conducted to assess the effect of *Group* on *Unique Errors.* It was identified that there was no effect of *Group* on *Unique Errors* ($F(4, 70) = 1.71$, $p = .157$, partial $\eta^2 = .09$, power = .50)

A ONEWAY between groups univariate ANOVA (Analysis of Variance) was conducted to assess the effect of *Group* on *Correct Responses*. There was a significant effect of *Group* on *Correct Responses,* with the low perseverative error, high non-perseverative error older adults making the fewest correct responses ($F(4, 70) = 32.76$, $p < .001$, partial $\eta^2 = .65$, power approaching 1). Post hoc analyses were conducted using *Tukey's HSD* with $\alpha = .05$. It was identified that that the low perseverative error, high non-perseverative error responding older adults made significantly fewer correct responses than low perseverative error older adults, high perseverative error older adults, middle old, and younger adults. Again, this indicates that low perseverative error, high non-perseverative error older adults had difficulty on the task.

A ONEWAY between groups univariate ANOVA (Analysis of Variance) was conducted to assess the effect of *Group* on *Perseverative Responses*. There was a significant effect of *Group* on *Perseverative Responses,* with the low perseverative error, high non-perseverative error older adults making the fewest perseverative responses ($F(4, 70) = 38.17$, $p < .001$, partial $\eta^2 = .69$, power approaching 1). Post hoc analyses were conducted using *Tukey's HSD* with $\alpha = .05$. The low perseverative error, high non-perseverative error responding older adults made significantly fewer perseverative responses, than low perseverative error older adults, high perseverative error older adults, middle old, and younger adults. In addition, the low perseverative error older adults were significantly different from the high perseverative error older adults, with fewer perseverative responses

made. As mentioned previously, perseveration requires an individual to remember the response strategy they were using. Therefore, this may indicate a memory deficit in this cohort.

A ONEWAY between groups univariate ANOVA (Analysis of Variance) was conducted to assess the effect of *Group* on *Number of Trials.* It was identified that there was no significant effect of *Group* on *Number of Trials* ($F(4, 70) = 1.39$, $p = .246$, partial $\eta^2 = .08$, power = .41).

A ONEWAY between groups univariate ANOVA (Analysis of Variance) was conducted to assess the effect *Group* on *Trials to Complete First Category.* There was a significant effect of *Group* on *Trials to Complete First Category*, with low perseverative error, high non-perseverative error older adults taking significantly fewer trials to complete their first category than middle old, high perseverative error, and low perseverative error older adults, as they were unable to complete any categories on the task ($F(4, 70) = 12.18$, $p < .001$, partial $\eta^2 = .41$, power approaching 1). Post hoc analyses were conducted using *Tukey's HSD* with $\alpha = .05$. The low perseverative error, high non-perseverative error older adults took significantly fewer trials to complete their first category than low perseverative error older adults, high perseverative error responding older adults, and middle old. In addition, low perseverative error older adults were significantly different from high perseverative error older adults, middle old, and younger adults as they took more trials to complete their first category. As the low perseverative error, high non-perseverative error older adults scored 0, this indicates they were unable to complete any categories on the task. This provides further evidence that decline in cognitive functioning is most evident in the low perseverative error, high non-perseverative error older adult sample.

A ONEWAY between groups univariate ANOVA (Analysis of Variance) was conducted to assess the effect of *Group* on *Categories.* There was a significant effect of

Group on *Categories* with low perseverative error, high non-perseverative error older adults completing the fewest categories on the task ($F(4, 70) = 19.86$, $p < .001$, partial $\eta^2 = .53$, power approaching 1). Post hoc analyses were conducted using *Tukey's HSD* with $\alpha = .05$. The low perseverative error, high non-perseverative error older adults completed significantly fewer categories than low perseverative error older adults, high perseverative error older adults, middle old, and younger adults As mentioned previously, this suggests that the low perseverative error, high non-perseverative error are lower functioning than the other adult cohorts as they were unable to complete any categories at all.

A ONEWAY between groups univariate ANOVA (Analysis of Variance) was conducted to assess the effect of *Group* on *Perseverative Runs*. There was also effect of Group on *Perseverative Runs,* with the low perseverative error, high non-perseverative older adults making the fewest perseverative runs ($F(4, 70) = 2.83$, $p = .031$, partial $\eta^2 = .14$, power = .74). Post hoc analyses were conducted using *Tukey's HSD* with $\alpha = .05$. Although there was a significant result, there were no differences between the 4 groups.

A ONEWAY between groups univariate ANOVA (Analysis of Variance) was conducted to assess the effect of *Group* on *Latency to Identify Neutral Words*. There was a significant effect of *Group* on *Latency to Identify Neutral Words,* with the low perseverative error and low perseverative error, high non-perseverative error older adults taking significantly longer to identify the colour of the neutral words than young and middle old adults ($F(4, 70) = 18.81$, $p < .001$, partial $\eta^2 = .52$, power approaching 1). Post hoc analyses were conducted using *Tukey's HSD* with $\alpha = .05$. The low perseverative error, high non-perseverative error older adults took significantly longer to identify the colour of the neutral words than young and middle old adults. However, they were not significantly different from high perseverative error older adults or low perseverative error older adults. The low perseverative error older adults also took significantly longer to identify the colour of the

neutral words than young and middle old adults. In addition, the high perseverative error older adults took significantly longer to identify the colour of the neutral words than younger adults.

A ONEWAY between groups univariate ANOVA (Analysis of Variance) was conducted to assess the effect of *Group* on *Latency to Identify Semantically Incongruent Words*. There was a significant effect of *Group* on *Latency to Identify Semantically Incongruent Words,* with low and high perseverative error older adults taking significantly longer to identify the colour of the semantically incongruent words than young and middle old adults ($F(4, 70) = 11.71$, $p < .001$, partial $\eta^2 = .40$, power approaching 1). Post hoc analyses were conducted using *Tukey's HSD* with $\alpha = .05$. It was identified that the low perseverative error, high non-perseverative error older adults took significantly longer to identify the colour of the semantically incongruent words than young adults. However, they were not significantly different from high perseverative error older adults or low perseverative error older adults. In addition, they were not significantly different from the middle old adults. The low perseverative error older adults also took significantly longer to identify the colour of the semantically incongruent words than young and middle old adults. In addition, the high perseverative error older adults took significantly longer to identify the colour of the semantically incongruent words than younger and middle old adults. From the above, it suggests that the older adult cohorts had difficulty in inhibiting automatic responses in the presence of conflicting choices, resulting in longer latencies on the task.

A ONEWAY between groups univariate ANOVA (Analysis of Variance) was conducted to assess the effect of *Group* on *Mean Span.* There was no significant effect of *Group* on *Mean Span* ($F(4, 70) = .23$, $p = .920$, partial $\eta^2 = .01$, power = .10. A ONEWAY between groups univariate ANOVA (Analysis of Variance) was conducted to assess the

effect of *Group* on *Mean Latency.* In addition, there was no significant effect of *Group* on *Mean Latency* ($F(4, 70) = 2.43$, $p = .056$, partial $\eta^2 = .12$, power = .67).

From the additional analysis, there is some evidence that the low perseverative error, high non-perseverative error older adults are showing more evidence of cognitive decline than the other older adult cohorts. However, these results are only preliminary and must be interpreted with caution.

Discussion

From the research (e.g., Sorrel & Pennequin, 2008) there is evidence of age related decline in executive functioning. In particular, there is some indication that the ability to shift from one problem solution to another declines with age. Therefore, it was expected that older adults would show more evidence of perseveration than younger cohorts.

From the Wisconsin Card Sorting Test, it was found that the older adults did not make significantly more perseverative errors than the other cohorts. Based on the literature (e.g., Berg, 1948) there is some indication that older adults have decline in the ability to shift between set. Although it was found middle old adults made more perseverative errors than younger adults, older adults did not. However, there was evidence of heterogeneity in the older adult sample, suggesting some of the cohort also had a tendency to make perseverative errors. When the older adults were divided based on functional performance, it was found that the higher scoring cohort made significantly more perseverative errors than the younger, middle old, and low perseverative error adult group. This suggests that this cohort of older adults had difficulty shifting from a rigid mental set, consequently making more perseverative errors.

Initially, the number of perseverative responses was not significantly affected by age. However, when the older adult cohort was differentiated into two groups, the high

perseverative error older adults also made significantly more perseverative responses than the young, middle old, and low perseverative error older adults. This also provides evidence that this cohort of older adults have decline in shifting. Similar to perseverative responses, perseverative runs was initially not significantly affected by age. When the older adult cohort was differentiated into two groups, it was found that the high perseverative error older adults made significantly more perseverative runs than the young and low perseverative error older adults. Again, this provides evidence of decline in shifting.

As there was some evidence of perseveration in some of the older cohort, there results provide partial support for the research of Delaloye et al. (2009) who found that global-local shifting was significantly affected by age. They also provide partial support for Sorel and Pennequin (2008) who assessed shifting using a Plus Minus task and found that the oldest group had a significantly higher cost of shifting on the measure in comparison to the two younger cohorts. In addition, Berg (1948) found that older participants (aged 58-74) perseverated in their original responding strategy and consequently were unable to complete any categories on the Wisconsin Card Sorting Test.

There was an effect of age on non-perseverative errors, with older adults making more non-perseverative errors than young and middle old adults. When the cohort was divided into two, it was found that low perseverative error older adults made significantly more non-perseverative errors than young, middle old, and high perseverative error older adults. This suggests that the low perseverative error adults had more of a tendency to make errors that did not reflect a rigid responding strategy. The high perseverative error older adults did not make significantly more non-perseverative errors than young and middle old adults. As there was evidence of heterogeneity in the low perseverative error older adults, the group was further differentiated based on number of non-perseverative errors made. When the low perseverative error older adult cohort was further divided, it was found that the low

perseverative error, high non-perseverative error older adults made significantly fewer non-perseverative errors than all other groups.

It was also found that there was also a marginal significant effect of age on unique errors. There was some evidence that older adults made more unique errors than the middle adults. Unique errors are matches that are not based on any of the three sorting principles (colour, form, number). From the exploratory analysis, there was no difference in unique errors made.

Although no effect of age on number of trials completed was identified, there was a significant effect on the number of trials taken to complete the first category. It was found that middle older adults took significantly more trials to complete the first category than younger adults, however, the older adults did not. Again, there was evidence of heterogeneity in the sample, suggesting that some of the older adults took more trials than others to complete their first category.

When the older adult cohort was divided into two, neither the high or low perseverative error older adults were significantly different from the younger adults. When the older adults were divided into three groups, it was found that the low perseverative error, high non-perseverative error older adults did not complete their first category. This might indicate that this cohort was unable to remember a particular responding strategy. Consequently, they were unable to complete their first category.

There was evidence of a linear decline with age for the number of categories completed, with older adults completing the fewest categories. In the exploratory analysis, it was identified that both high and low perseverative error older adults completed significantly fewer categories than the younger adults. In addition, the low perseverative error older adults completed significantly fewer categories than the middle old adults. In further exploratory

analysis, it was found that the low perseverative error, high non-perseverative error older adults did not complete any categories. Again, this may be indicative of a memory deficit.

In addition, there was evidence of a linear decline with age in the number of total errors made. When the older adults were differentiated into two cohorts, both groups were found to make more total errors than young and middle adults. This suggests that older adults had general difficulty on the task. In the additional exploratory analysis, the low perseverative error, high non-perseverative error older adults made significantly more total errors than the other older adult cohorts. As this cohort was found to make more total errors, unable to complete any categories and did not perseverate, this might indicate a failure to remember the nature of the task.

There is also some indication in the literature (e.g., Crawford et al., 2007) that older adults have difficulty with inhibiting automatic response patterns. Therefore, it was also expected that older adults would take longer to name the colour of the words on the semantically incongruent condition of the Stroop Test than younger adults. It was found middle and older adults were significantly slower in the identification of neutral words than younger adults. As expected, older adults were significantly slower than the young and middle old adults in the identification of semantically incongruent words. This provides an indication that older adults have difficulty inhibiting automatic responses in the presence of conflicting choices. This finding is consistent with Sorel and Pennequin (2008) who also using the Stroop Test found there was a significant decline with age. This phenomena can be explained based on the framework of Hasher et al. (1999) discussed earlier in that with the presentation of two conflicting stimuli, the automatic response is to identify the semantic meaning of the word and when there is the realisation that there is a difference in the colour of the word, this creates a “cross talk” and increases latency to respond. Alternatively, the increase in latency could also be as a result of neuropathy from cell death of direct

connections. Stern (2009) argued that instead of direct retrieval of information from activation of the semantic associative networks, that older adults must use redundant secondary pathways to access information. As this process utilises indirect associations in the retrieval of information, older adults are likely to be slower as a consequence of the age related neuronal changes that have impaired direct pathways to the required information in the primary network. Based on the findings, there is evidence for deficit in response inhibition. That is that incongruent stimuli troubled the oldest participants more than any other group.

Although there was age related decline in executive functioning, no accompanying decline for short-term memory performance was observed. This finding is not surprising as there is an argument in the literature (e.g., Luo & Craik, 2008; Nilsson, 2003), to suggest that the ability to retain information for brief periods in memory storage remains relatively intact over time. However, there was a significant difference in latency with older adults taking significantly longer on the task than younger adults. The preservation of short-term memory and increase in latency supports the *cognitive reserve hypothesis.* This might suggest that over time, the older adults have learned to use the alternate pathways to access information utilising the cognitive reserve for short-term retrieval of information. As a result, they are still able to retrieve the information accurately, but take longer due to the use of more redundant, secondary pathways.

Overall Conclusions

From the Wisconsin Card Sorting Test, it was found older adults made significantly more total errors, non-perseverative errors and completed fewer categories than young and middle old adults. Initially, it was found that older adults did not perseverate, which is contrary to the literature. However, there was also some indication of heterogeneity in the older adults, suggesting multiple groups existed within the cohort. When the older adults

were differentiated based on performance, it was found that one cohort demonstrated evidence of perseveration. This provided some evidence that older individuals have decline in their ability to shift between sets. In addition, they completed fewer categories than young adults and made more total errors than both young and middle old adults. Further evidence of change in executive function was found on the Stroop Test. This cohort was also significantly slower in the identification of semantically incongruent words than young and middle old adults, suggesting decrement when presented conflicting response choices. However, they show no evidence of decline in short-term memory. This pattern suggests that this cohort have decrement in shifting and response inhibition. However, their short-term memory appears to be relatively intact.

It was identified that the low perseverative error older adults made significantly more non-perseverative errors on the Wisconsin Card Sorting Test compared to high perseverative error older adults. They also made significantly more total errors and completed fewer categories than the young and middle old adults, suggesting they had general difficulty on the task. However, they did not perseverate, which may indicate this cohort did not decline in shifting. In addition, they were significantly slower in the identification of semantically incongruent words on the Stroop Test than younger and middle old adults. Again, this suggests deficit in response inhibition. Similar to the high perseverative error older adults, there was no evidence of decline in short-term memory.

It was identified that the low perseverative error, high non-perseverative error older adult group made significantly more total errors and non-perseverative errors on the Wisconsin Card Sorting Test than young, middle old, low perseverative error and high perseverative error older adults. They were unable to complete the first category, or in fact any categories at all. In addition, they show no evidence of perseveration. Further evidence of decline was identified in the Stroop Test, as they were also slower to identify the colour of

semantically incongruent words than young adults. Again, there appears to be no significant decline in short-term memory performance. A generalised poor performance without an accompanying decline in span is surprising. This could suggest that the span test is a relatively insensitive measure of cognitive decline. Despite not finding decline in span, there is still evidence that this cohort is lower functioning than the other older adults. However, these findings are only preliminary and must be interpreted with caution due to the small sample sizes.

In addition, there was some evidence of executive functioning decline in the middle older adults. From the Wisconsin Card Sorting Test, it was identified that the middle old adults made more perseverative errors than the young adults. This may indicate that perseveration and inability to shift begins in middle adulthood. This was further supported in that they took significantly more trials to complete their first category than younger adults. Similar to the older adults, the middle old adults made significantly more total errors and completed fewer categories on the task than the younger adults. From the Stroop Test, middle old adults were slower to identify the colour of neutral words than younger adults. As both tasks were capable of detecting differences in the middle old adults, this might suggest they have utility as a screening measure in the detection of incipient cognitive decline.

From this study, there is evidence of age related decline in executive functioning. In addition, there was some evidence of executive functioning decline in the middle old adults. However, no age differences were identified in short-term memory performance. As there was decline in executive functioning but that short-term memory remained preserved, this provides evidence for modular decline with increasing age.

In the next study, age related decline in emotion recognition was assessed. Emotion recognition was used as it has been thought to decline with increasing age (e.g., Ruffman et al., 2008). Memory processes were also investigated as there is some evidence (e.g., Smith &

Winograd, 1978) that decline in emotion recognition may reflect simple non-verbal memory failure. From the current study (Study 1) there was little evidence of decline in verbal memory. There is still some debate as to the mechanisms of age related decline. To further clarify whether decline is the result of generalised damage or the failure of particular subsystems was the aim of the next study. If decline in emotion recognition is accompanied by decline more broadly in cognitive function (for example, in associated declines in both verbal and non verbal memory), the argument may be made that decline is generalised. Decline in emotion recognition accompanied by change in non-verbal memory dissociated from verbal memory (that is, no change in verbal memory) would on the other hand be more consistent with a view of cognitive ageing as being modular in nature.

Chapter 4

Study 2: Assessing differences in emotion recognition, non-verbal memory and verbal memory between young old, middle old and older adults

An intriguing claim of the past decade has been that the ability to recognise emotions declines with age (e.g., Ruffman, Livingstone & Phillips, 2008). This seems like an unlikely finding, however it may be that decline in the recognition of emotions indicates modular decline of cognitive function. It has been posited that emotion recognition may be associated with activation of the amygdala and prefrontal cortex (Ritchey, Bessette-Symons, Hayes, & Cabeza, 2011). One explanation is that these regions are declining at a faster rate than other parts of the brain or are more vulnerable to disease or aging processes and this is reflected in the selective impairment of some aspects of cognition such as emotion recognition. Another possibility is that decline in emotion recognition may be indicative of a form of memory deficit in the older adults. There is some evidence in the literature that non-verbal memory may be more susceptible to age related decline in older adults than verbal memory. However, conventional measures of verbal memory show little decline with increasing age in healthy individuals.

Emotion Recognition

Recently, evidence has been reported of age related decline in emotion recognition (Issacowitz et al., 2007). In particular, it has been found that older adults have difficulty in recognising negative emotions such as anger. Issacowitz et al. (2007), McDowell, Harrison, and Demaree (1994) and Suzuki et al. (2007) found older adults were significantly less accurate in recognising angry faces than younger adults. Calder et al. (2003) also observed some evidence of age related decline in recognising angry faces. Mill et al. (2009) also found adults (over the age of 50) were significantly less accurate in recognising angry faces than

younger adults (18-40). From the summary of literature in Issacowitz et al. (2007), which expanded on the work of Sullivan and Ruffman (2004), it was identified in 10 out of 13 studies that older adults had significantly less accurate recognition of anger than younger adults. In addition, in a meta-analysis that assessed data from 17 studies conducted by Ruffman, Henry, Livingstone, and Phillips (2008), it was found older adults had significantly less accurate recognition of angry faces than younger adults. These studies provide evidence for age related decline in anger recognition. However, the case is by no means settled, Issacowitz et al. (2007) identified two studies that found older adults were not significantly different from younger adults. In addition, Issacowitz et al. (2007) in their own research identified no age differences for anger on the facial recognition task. Despite these studies not finding evidence of decline, indications persist that older adults recognition of anger is less accurate than younger adults.

Likewise, there is evidence for age related decline in the recognition of sadness. Moreno et al. (1993) found older adults were significantly less accurate in recognising sad faces than young and middle old adults. McDowell et al. (1994) and Suzuki et al. (2007) found older adults were significantly less accurate in recognising sad faces than younger adults. Calder et al. (2003) also observed some evidence of age related decline in the recognition of sad faces. Issacowitz et al. (2007) found middle and older adults scored significantly lower than younger adults on the lexical task. From the summary of literature in Issacowitz et al. (2007), 10 out of 14 studies found older adults had significantly less accurate recognition of sadness than younger adults. In a meta-analysis, Ruffman et al. (2008) identified older adults had significantly less accurate recognition of sad faces than younger adults. Mill et al. (2009) also found that there was a decrease in recognition of sad faces from the age of 40.

However, the exact nature of the decline and its mechanism remain unclear. Four studies identified by Issacowitz et al. (2007) did not find evidence of decline in recognition of sadness. Moreover, Issacowitz et al. only identified an age effect on the lexical task but not on the facial recognition task. Despite these studies finding that older adults performed similarly to younger adults, there is still a balance of evidence for decline in sadness recognition.

There is also some evidence for age related decline in the recognition of fear. This was supported by the research of McDowell et al. (1994), who identified older adults had significantly less accurate recognition of fearful faces than younger adults. Moreover, there is evidence for decline in the research by Calder et al. (2003) who found the strongest age effect in recognition of fearful faces. Issacowitz et al. (2007) found older adults had significantly less accurate recognition of fearful faces than young and middle old adults. From the summary of literature in Issacowitz et al. (2007), 6 out of 11 studies found that older adults had significantly less accurate recognition of fearful faces than the younger adults. This was further supported in the meta-analysis conducted by Ruffman et al. (2008), who identified older adults had significantly less accurate recognition of fearful faces than younger adults. Mill et al. (2009) also found the oldest adult cohort (over the age of 61) were significantly less accurate in recognising fearful faces than the younger cohorts (18-40).

Again, the exact nature of the decline and its mechanism remain unclear. Although Issacowitz et al. (2007) found an age effect on the facial recognition task, this was not observed on the lexical task. In addition, Suzuki et al. (2007) and five studies reported by Issacowitz et al. (2007) did not find older adults to decline in recognition of fearful faces. Despite these studies finding older adults performed similarly to younger adults, there is again a balance of evidence for decline in fearful recognition.

Contempt, which could also be classified as a negative emotion, has not been studied extensively and sparse literature exists in relation to how well the elderly recognise it. In Mill et al. (2009)'s research, age related decline in contempt recognition after the age of 61 was found. Due to the paucity of literature, contempt recognition was also assessed in the current study.

It is also unclear whether age related decline for recognition of emotions extends to disgust faces, as there is some evidence that disgust recognition may even improve with age. This was supported by Calder et al. (2003) who found a significant age related increase in recognition of disgust faces. Suzuki et al. (2007) also found older adults were more accurate in recognising disgust faces than younger adults. From the summary of literature in Issacowitz et al. (2007), 5 of the 10 studies found older adults had similar recognition and 3 found older adults were more accurate in recognising disgust faces than younger adults. This was also supported in the meta-analysis conducted by Ruffman et al. (2008) who identified older adults were more accurate in recognising disgust faces than younger adults.

Despite evidence for preservation or even an age related increase in disgust recognition, Issacowitz et al. (2007) found middle and older adults scored significantly lower than younger adults on the facial and lexical tasks. In addition, Mill et al. (2009) found the oldest age cohort (over the age of 61) were significantly less accurate in the recognition of disgust faces than the younger cohorts (18-60). Issacowitz et al. (2007) also reports two studies found older adults were less accurate in recognising disgust than younger adults. Despite these studies finding evidence of decline, indications persist that recognition of disgust remains preserved from aging.

Calder et al. (2003) argued based on other research that the use of different neural areas might explain preservation of disgust and the opposite age related decline in fear recognition. Based on the evidence that has found separate neural subsystems for the

processing of fear and disgust, Calder et al. (2003) suggested that this might indicate a dissociation of process. However, the problem with this argument is that there are inconsistent findings of emotion recognition in the literature and that some research has found disgust recognition to decline and fear recognition to remain intact. In addition, Calder et al. (2003) formulated their argument based on research that has mainly assessed individuals with other neurological damage such as Huntington's disease. Therefore, despite older adults displaying similar behavioural patterns, it is unlikely that they would use the same neural structures in processing emotions. The third study ahead (Chapter 4) discusses emotion processing in older adults.

There is also some evidence that surprise recognition may not decline with age. In Issacowitz et al. (2007), no age differences were identified on the facial task. From the summary of literature in Issacowitz et al. (2007), older adults in all 9 studies had similar recognition of surprised faces to younger adults. Ruffman et al.'s (2008), meta-analysis also found older adults had similar recognition of surprised faces to younger adults. Although there is some evidence suggesting a lack of age related decline in surprise recognition, this could also indicate a task characteristic. In the meta-analysis (Ruffman et al., 2008), and summary of research in Issacowitz et al. (2007), the majority of studies used facial expressions from Ekman and Friesen. However, Mill et al. (2009) found that the oldest age cohort (over the age of 61) had significantly less accurate recognition of surprised faces than the younger cohorts (18-40). In addition, Issacowitz et al. (2007) found middle and older adults scored significantly lower on the lexical task. It is possible that some of the inconsistencies in the current literature relate to methodological limitations including stimulus artefacts and floor or ceiling effects. The current study uses a revised stimulus set to produce a consistent set of emotional cues and hence reduce the potential of ceiling effects.

Whilst it is generally claimed that age related changes in emotion recognition are most evident for negative emotions such as anger, the research regarding happiness recognition is inconclusive. There is some evidence that recognition of positive affect may remain preserved or improve with age. Moreno et al. (1993) found middle old and older adults were more accurate in recognising happy faces than younger adults. McDowell et al. (1994) and Issacowitz et al. (2007) found older adults had similar recognition of happy faces to young adults. Similarly, Issacowitz et al. (2007) found in 11 out of 13 studies that older adults had similar happiness recognition to younger adults. This might suggest that older adults are still able to recognise happy faces. However, Issacowitz argues that ceiling effects may have confounded the happiness data. Therefore, it is difficult to assess whether the lack of age related decline in these studies reflects genuine robustness or is indicative of a task artefact.

Neutral recognition has not been studied extensively and sparse literature also exists to how well the elderly recognise it. McDowell et al. (1994) found older adults were less accurate in recognising neutral faces than younger adults. In the summary of studies identified by Issacowitz, one study found evidence of age related decline in neutral recognition. However, the other study identified found no differences with age. Although Issacowitz et al. (2007) observed no differences in age on the facial task, middle and older adults scored significantly lower than younger adults on the lexical task. To clarify the inconsistencies in the literature, neutral recognition was assessed in the current study.

The nature of age related changes in emotion processing, particularly in the recognition of faces remains unanswered. In the current study, age related decline in emotion recognition and mechanism by which it occurs was investigated. It could be argued that decline in emotion recognition may result from changes in the visual representation of the stimulus (non-verbal memory).

Non-Verbal Memory

One possible explanation for age related decline in emotion recognition might simply be the older individual has forgotten what the face looks like. If so, we should expect to see decline in emotion recognition associated with decline in non-verbal memory. Riege and Inman (1981) assessed memory for non-verbal stimuli using geometric art patterns in a sample that was divided into six age cohorts ranging from 28 to 84 years. Riege and Inman found the two older age groups (60s and 70s) made significantly fewer correct responses on the task when compared to the younger age cohorts. In addition, there was an age related decrease in *d*'[9] identified across age cohorts. Trahan et al. (1986) also examined memory for non-verbal stimuli using line drawings of flowers and different varieties of animals and insects with a sample that was divided into eight separate age cohorts. Trahan et al. found some evidence for an age related decrease in performance, with a lower hit rate for the two older age cohorts (66-77 and 78-89) compared with the younger cohorts.

Age related decline for non-verbal memory has also been found when using faces as stimuli. Smith and Winograd (1978), examined memory for faces with additional instructional manipulation condition. Half of the participants were provided standard learning instructions, and the other half were provided an elaborate encoding task where they had to attend to a structural characteristic of the face and indicate whether the face looked friendly. Smith and Wingrad found a significant effect of instruction on recognition (*d'*) with the more elaborate condition leading to better memory. In addition, they found that older participants had a significantly lower *d'* than younger participants. Ferris, Crook, Clark, McCarthy, and Rae (1980) also administered a memory for faces task and found that older adults and cognitively impaired older individuals had a significantly lower *d*' when compared to the younger adults. However, it was also identified that the older adults and cognitively impaired

[9] *d'* statistic measures the ability of a subject to discriminate an old item from distractor items…." (Ferris et al., 1980, p.708). The d' also takes into account false alarm rate (Ferris et al. 1980)

older individuals were not significantly different from one another. The authors suggest that since the two elderly groups did not differ from each other, this might indicate that the impairment is due to a normal aging process, rather than a disease pathway. In addition, Crook and Larrabee (1992) using a computerised memory for faces task, found decline in non-verbal memory from the age of 50. However, the most significant age related decrements were evident in participants who were aged 70 years or older.

Refer to Figure 6 below for how a decline in emotion recognition might be explained by decline in non-verbal memory.

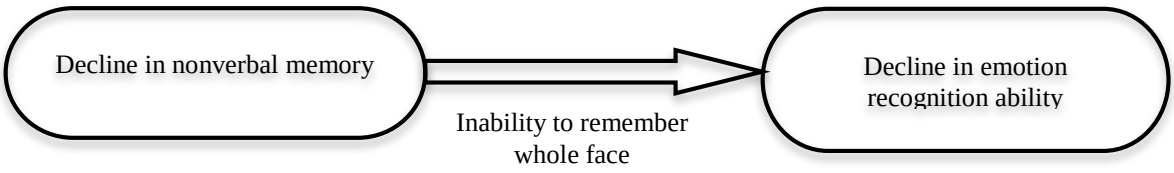

Figure 6. Non-Verbal Memory Decline Argument in Explaining Emotion Recognition Decline

Verbal Memory

There is some indication that age related decline in emotion recognition might be attributed to non-verbal memory. However, little differences in verbal memory are seen across the lifespan. In the previous study, no evidence of age related decline was found for verbal memory (digit span). In addition, Nilsson (2003) argued that short-term memory decline may be task dependent and that tasks involving only the maintenance of information are less likely to be affected by aging than tasks involving the manipulation and maintenance of information in memory. Therefore, it might be that age related decline of verbal memory is dependent on task difficulty. Based on the previous study, it is unlikely age differences will be found on the verbal memory measure (span).

Aims of Research

From the previous research, there is some evidence in age related decline of emotion recognition. Therefore, an aim of the current study was to assess whether older adults decline in the recognition of emotional stimuli (faces). Based on the research (e.g., Issacowitz et al., 2007), it was predicted that older adults would have significantly poorer recognition of faces than the younger cohorts on the emotion recognition task.

A further aim was to assess whether decline in emotion recognition could be attributed to change in verbal or non-verbal memory, as well as to assess whether age related cognitive decline is generalised or modular. For example, if decline in nonverbal memory is observed but that verbal memory remains intact, this would provide evidence for dissociation of memory processing and support a theory that age related changes occur in distinctive parts of the brain that decline at different rates. From the literature (e.g., Ferris et al., 1980) there is some evidence for an age related decline in non-verbal memory. However, there is evidence from the previous study to suggest that verbal memory might remain preserved. Therefore, it

was also predicted that decline in emotion recognition would be attributed to non-verbal rather than verbal memory decline.

Method

Participants

A sample of 62 participants was recruited from South-Eastern Queensland to participate in the study. A purposive sampling technique was used. Although purposive sampling is not as effective as stratified random sampling and is not be representative of the population, this technique is useful in gathering participants that share particular characteristics (Babbie, 2007). In this research, the particular characteristic of interest was independent living healthy older adults. The participants that comprised the young old sample were first year psychology students from a university that received course credit for participation in the research. The other participants were from the local community. Screening of the data lead to the final sample of 62 comprising of 48 females (77.4%) and 14 males (22.6%). The age of the participants ranged from 18 to 84 years (M = 50.47, SD = 20.83). For the entire sample, 28 participants (45.2%) were taking medication for illnesses e.g., high blood pressure, high cholesterol, diabetes, depression, vascular problems and 34 (54.8%) were not taking medication. Forty-one (66.1%) nominated high school, 13 (21.0%) nominated university, 6 (9.7%) nominated T.A.F.E/college and 2 (1.3%) nominated primary school as highest level of education obtained. Chi-square analysis was also conducted to assess whether there was a difference in medical status by gender. However, this was not significant (χ^2 (1, n = 62) = 2.67, p = .102). Refer to Table 13 below.

Table 13

Cross-Tabulation of Medical Status x Gender

Gender	Medical Status	
	Taking medication	Were not taking medication
Males	9(14.5%)	5(8.1%)
Females	19(30.6%)	29(46.8%)

The participants were divided into three groups depending on age. The younger adults group (18-49) consisted of 21 participants with ages ranging from 18 to 49 (*M* = 24.71, *SD* = 9.32) with 18 (85.7%) females and 3 (14.3%) males. From the sample, 17 (81.0%) participants nominated high school and 4 (19.0%) university as the highest level of education obtained. One participant (4.8%) was taking medication for illnesses e.g., high blood pressure, high cholesterol, diabetes, depression, vascular problems. Twenty (95.2%) participants were not taking medication.

The middle adults group (50 to 64) consisted of 21 participants with ages ranging from 50 to 64 (*M* = 57.29, *SD* = 4.60) with 18 (85.7%) females and 3 (14.3%) males. From the sample, 9 participants (42.9%) nominated high school, 6 (28.6%) university, 5 (23.8%) T.A.F.E/College and 1 primary school (4.8%) as highest level of education obtained. Nine (42.9%) of the participants were taking medication for illnesses e.g., high blood pressure, high cholesterol, diabetes, depression, vascular problems. Twelve (57.1%) participants were not taking medication.

The older adults group (65 and above) consisted of 20 participants with ages ranging from 65 to 84 (*M* = 70.35, *SD* = 4.42) with 12 (60.0%) females and 8 (40.0%) males. From the sample, 15 (75.0%) nominated high school, 3 (15.0%) university, 1 (5.0%)

T.A.F.E/College and 1 (5.0%) nominated primary school as highest level of education obtained. Eighteen (90.0%) of the participants were taking medication for illnesses e.g., high blood pressure, high cholesterol, diabetes, depression, vascular problems. Two (10.0%) participants were not taking medication.

Chi-square analysis was also conducted to assess whether there was a difference in medical status by age and was found to be significant ($\chi^2(2, n = 62) = 30.12, p < .001$). Refer to Table 14 below.

Table 14

Cross-Tabulation of Medical Status x Gender

	Medical Status	
Age	Taking medication	Were not taking medication
Young Old	1 (1.6%)	20 (32.3%)
Middle Old	9 (14.5%)	12 (19.4%)
Older Adults	18 (29.0%)	2 (3.2%)

Instruments

Verbal memory. To assess verbal memory, a digit span task was used which is designed to assess an individual's ability to keep information in short-term memory storage. The stimuli for this task were sets of numerical digits. The lowest number presented was one digit and the highest that could be reached was 15 digits. It was expected that healthy individuals would recall 7 +/ 2 digits (Miller, 1994).

The task was formulated using a stair case method where once an estimate of response threshold was obtained; stimuli were never presented far from this threshold

(Kantowitz et al., 2009). The first trial began with three digits presented and each ongoing presentation would subsequently increase depending on correct recall. The sequence of numbers would continue to increase if correct and drop back a digit if an incorrect sequence was recalled. The task would end either when the participant had reached maximum span performance or once 30 trials had been completed. The 30 trials ensured maximum span performance was obtained. An average of 5 trials for both accuracy and latency was taken to obtain span performance. The data was taken from trials 12-17 to reduce the potential of practice and fatigue effects which may have occurred during the start or end trials; thereby ensuring the most reliable measure of performance.

For each trial, the display time of the stimuli was 3000 ms to ensure sufficient encoding of the digits. A 2000 ms blank time was presented and then participants were provided 10000 ms to recall each trial of digits. Once 10000 ms had been reached, a timeout would occur and the next trial would be presented with one digit removed.

Non-verbal memory. To assess nonverbal memory, a memory faces for task was used. The database of faces was comprised of photographs taken from a cohort of students at a university in southeast Queensland. All photographs were of neutral faces with no piercings and hair removed to minimize the chance of recognizing the face by a particular attribute. Refer to Figure 7 for examples of the stimuli used in the task.

Figure 7. Stimuli from the Memory for Faces Task

Prior to the commencement of the task, participants were provided a learning phase with 20 faces presented individually on the screen. The display time of each stimulus was 2000 ms to ensure sufficient encoding of the face. A blank time of 100 ms was shown between each presentation to allow the participant to reset before the next face was presented. The experimental phase was self-paced. Participants were presented 60 trials and required to respond either yes or no as to whether they had seen the face previously. Each button had a label underneath which stated Press Z and Press / for Yes and No Responses respectively.

Emotion recognition. To assess emotion recognition, a face recognition task requiring participants to identify specific emotions (neutral, sad, happy angry, disgusted, contempt, surprise, fearful) was used. The images used in this task were of a young man, young woman, older man and older woman that were manipulated into the eight facial expressions (neutral, sad, happy, angry, disgusted, contempt, surprise, fearful) also using the computer program Crazy Talk 6 (Reallusion Inc, 2012). The software utilises a standard algorithm to distort a neutral image systematically to express emotional states by morphing facial features. To reduce the likelihood of cohort familiarity effects (e.g., young adults performing better on younger faces), both young and old faces portraying the different facial

expressions were used. Refer to Figure 8 for the emotions expressed by the elderly man used in the task.

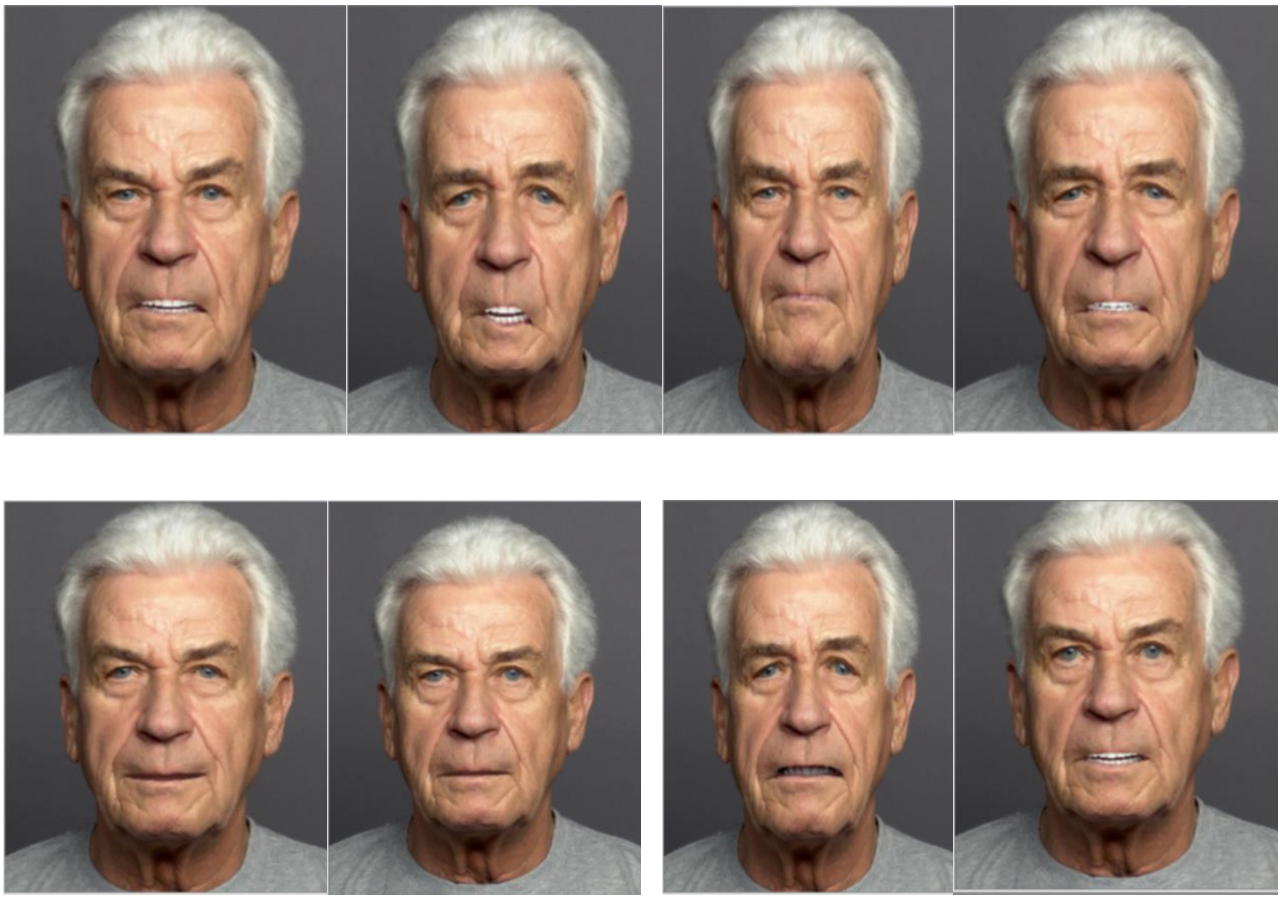

Figure 8. Emotions Expressed by Elderly Man in Emotion Recognition Task

Participants were presented with 100 trials of four different aged individuals (young man, young woman, elderly man or elderly woman) with one of the eight facial expressions (neutral, sad, happy, angry, disgusted, contemptful, surprised, fearful). The stimuli were presented for 2000 ms to allow sufficient encoding of the face. A mask was then presented over the face so that the stimuli could not be seen. Participants were then provided 10000 ms to indicate which facial expression best matched the face presented on the screen. Once the face had been shown for 10000 ms, a time out would occur and the next face was presented. On each trial, the face was presented in the middle of the screen. A set of radio buttons

labeled with the eight expressions was presented each face. On each trial, participants were instructed to indicate which description best fit the facial expression presented.

Experimental hardware. Each of the tasks was visually presented on a 15 inch Toshiba Satellite L300 laptop. The laptop had an AMD Athlon 64 X 2 Dual-Core 2.8 GHz Processor running Windows 7 with 4GB of ram. The screen resolution was 32 bit and set at 1024 x 768 pixels

Procedure

A potential issue that can arise in memory testing is that performance can be decremented when people are in unfamiliar locations (Russo et al., 1999). Therefore, middle and older adult participants were tested in situ (home or office locations) in order to obtain the most accurate performance. Although younger participants were tested at university, this is a familiar environment and therefore performance is unlikely to be decremented. For older people, a university environment could be daunting and therefore some of the differences in test performance might just be a function of the site of testing. The second argument is that older people may be less mobile and subsequently less inclined to travel than younger participants. Prior to administration, the tasks were counterbalanced to reduce the potential of order effects. Participants were verbally instructed to read the instructions on the laptop screen and indicate that they understood prior to the commencement of each task.

Verbal memory. Prior to the commencement of the task, the following instructions were presented on the laptop screen:

'In this experiment we will investigate your short-term memory. You will be presented with "sets" of digits. Each new list is called a "repetition". Your task is to remember as many of the digits as you can in the sequence. You need to remember to press the enter key at the end of each set. Please wait for the instructions to appear on the screen asking you to enter the digits before typing the sequence. If you recall the sequence in correct order the

number of digits will increase by one. If you make an error the number of digits will be decreased by one. The experiment will end when you have completed 30 trials, or have exhibited stable recall'.

Non-verbal memory. Prior to the learning phase, the following instructions were presented on the laptop screen:

'You are about to be shown some faces, your task is to try to remember these faces. Each face will be shown for 2 seconds. The screen will blank for a short period between faces. Later you will be shown a second set and asked if you saw it during this phase'.

Prior to the experimental phase, the following instructions were presented on the laptop screen:

'You are about to be shown some pictures of faces. Some of these are faces you have seen before. If you have seen a face before press the yes button. If you have not seen the face before press the no button. Press the "Z" key for YES if you have seen the face before. Press the "/" key for NO if you have not seen the face previously.

Emotion recognition. Prior to the commencement of the task, the following instructions were presented on the laptop screen:

'You are about to be shown some faces, you have to tell me which description matches the face shown, by pressing number 1 to 8 on the keyboard.

Press 1 – if the face looks neutral

Press 2 – if the face looks sad

Press 3 – if the face looks happy

Press 4 if the face looks angry

Press 5 – if the face looks disgusted

Press 6 – if the face shows contempt

Press 7 – if the face looks surprised

Press 8 – if the face looks fearful

Design

Emotion recognition. A between subjects design was used. The independent variable was *Age* (Young (18-49), Middle Old (50-64), and Older Adults (65 and above)). The dependent variable was *Recognition of Emotional State (*Neutral, Happy, Surprised, Anger, Sad, Fear, Disgust and Contempt).

Verbal and nonverbal memory. A between subjects design was used. The independent variable was *Age* (Young (18-49), Middle Old (50-64), and Older Adults (65 and above)). The dependent variables were *Accuracy* (Mean Span, Target Accuracy, and False Negative) and *Latency* (Latency to Locate Target Face).

Mean Span is the number of digits recalled (measure of verbal memory). Target Accuracy is the number of target faces identified (measure of non-verbal memory). False Negative is the number of target faces incorrectly missed.

Results

Preliminary analysis

All data was screened and analysed using IBM SPSS Statistics 21.

Emotion recognition. Prior to analysis, the assumptions of MANOVA were tested. The assumption of sample size was met. Violations of normality were identified for all levels of the DV using Kolmogorov-Smirnov ($p < .05$) except for *Recognition of Happiness Emotional State.* However, MANOVA is robust to moderate violations of normality with larger sample sizes (Tabachnick & Fidell, 2007). The data were not multicollinear. No outliers were identified. The data were linear. The assumption of homogeneity of covariance matrices was met. No missing data was identified.

Verbal and nonverbal memory. Prior to analysis, the assumptions of MANOVA were tested. The assumption of sample size was met. Violations of normality were identified for *Target Accuracy* and *Latency* using Kolmogorov-Smirnov ($p < .05$). However, MANOVA is robust to moderate violations of normality with larger sample sizes[10]. The DVs of *Average Accuracy* and *False Negative* and *Target Accuracy* and *False Positive* were singular ($r = 1.00$). Consequently, the redundant variables of *Average Accuracy* and *False Positive* were removed from the final analysis. No outliers were identified. The data were linear. The assumption of homogeneity of covariance-matrices was met. No missing data was identified.

Main Analysis

As there was an unbalanced design, *gender* and *education* were not included in the final analysis.

Emotion recognition. A ONEWAY between groups MANOVA (Multivariate Analysis of Variance) was conducted to assess the effect of *Age* (Young Old (18-49), Middle Old (50-64), and Older Adults (65+)) on *Recognition of Emotional State* (Neutral, Happy, Surprised, Anger, Sad, Fear, Disgust and Contempt). α was set at .05 apriori. Analysis of the combined variables showed that there was a significant effect of *Age* on the combined variables of *Recognition of Emotional State* ($F_{wilks}(16, 104) = 4.45$, $p < .001$, partial $\eta^2 = .41$, power approaching 1). As the overall test of the weighted linear composite was significant, each of the dependent variables was then considered separately.

There was no significant effect of *Age* on *Recognition of Neutral Emotional State* ($F(2, 59) = .85$, $p = .433$, partial $\eta^2 = .03$, power = .19) (Refer to Table 15 below). In addition, there was no significant effect of *Age* on *Recognition of Happy Emotional State* ($F(2, 59) = 2.63$, $p = .081$, partial $\eta^2 = .08$, power = .50) (Refer to Table 15 below).

However, it was found that there was a significant effect of *Age* on *Recognition of Surprised Emotional State*, with older adults recognising fewer surprised faces than young and middle old adults ($F(2, 58) = 6.22$, $p = .004$, partial $\eta^2 = .17$, power = .88). To investigate group differences between *Age*, a series of post hoc analyses were conducted using *Tukey's HSD* with $\alpha = .05$. Tukey's test was used, as it is a moderately conservative post hoc to control for familywise error rate over entire sets of pairwise comparisons (Keppel & Wickens, 2004). There was a significant difference between young and older adults, with older adults recognising fewer surprised faces than young adults (Refer to Table 15 below). There was also a significant difference between middle and older adults, with older adults recognising fewer surprised faces than middle old adults (Refer to Table 15 below). However, there was no significant difference between young and middle adults (Refer to Table 15 below).

Table 15

Mean Recognition for Eight Facial Expressions Broken Down by Young Old, Middle Old, and Older Adults

	Age Group		
	Young Old	Middle Old	Older Adults
Variable	*M* *(sd)*	*M* *(sd)*	*M* *(sd)*
Neutral	.55 *(.16)*	.50 *(.12)*	.57 *(.21)*
Happy	.47 *(.18)*	.49 *(.18)*	.37 *(.20)*
Surprised	.43[a] *(.13)*	.41[c] *(.15)*	.28 *(.14)*
Anger	.42[ab] *(.13)*	.25 *(.15)*	.20 *(.09)*
Sad	.32 *(.22)*	.25 *(.17)*	.18 *(.14)*
Fear	.08 *(.10)*	.14[c] *(.09)*	.05 *(.08)*
Disgust	.12 *(.11)*	.13 *(.09)*	.13 *(.09)*
Contempt	.19 *(.14)*	24 *(.12)*	.20 *(.10)*

NB: a – Difference between young and older adults, b – Difference between young and middle old adults, c – Difference between middle and older adults

In addition, there was a significant effect of *Age* on *Recognition of Anger Emotional State*, with middle and older adults recognising fewer angry faces than younger adults ($F(2, 59) = 16.88$, $p < .001$, partial $\eta^2 = .36$, power approaching 1). To investigate group differences between *Age*, a series of post hoc analyses were conducted using *Tukey's HSD* with $\alpha = .05$. There was a significant difference between young and older adults, with older adults recognising fewer angry faces than young adults (Refer to Table 15 above). There was also a significant difference between the young and middle old adults, with middle old adults recognising fewer angry faces than young adults (Refer to Table 15 above). However, there was no significant difference between middle and older adults (Refer to Table 15 above).

There was no significant effect of *Age on Recognition of Sad Emotional State* ($F(2, 59) = 2.90$, $p = .063$, partial $\eta^2 = .089$, power = .55) (Refer to Table 15 above). However, there was a significant effect of *Age* on *Recognition of Fearful Emotional State*, with older adults recognising fewer fearful faces than middle old adults ($F(2, 59) = 4.65$, $p = .013$, partial $\eta^2 = .14$, power = .76). To investigate group differences between *Age*, a series of post hoc analyses were conducted using *Tukey's HSD* with $\alpha = .05$. There was a significant difference between middle and older adults, with older adults recognising fewer fearful faces than middle old adults (Refer to Table 15 above). However, there were no significant differences between young and middle adults or young and older adults. (Refer to Table 15 above).

There also was no significant effect of *Age* on *Recognition of Disgust Emotional State* ($F(2, 59) = .06$, $p = .940$, partial $\eta^2 = .00$, power = .06) (Refer to Table 15 above). In addition, there was no significant effect of *Age on Recognition of Contempt Emotional State* ($F(2, 59) = .84$, $p = .438$, partial $\eta^2 = .03$, power = .19) (Refer to Table 15 above).

Verbal and non-verbal memory. A ONEWAY between groups MANOVA (Multivariate Analysis of Variance) was run to assess the effect of *Age* (Young Old (18-49), Middle Old (50-64), and Older Adults (65+)) on *Accuracy* (Mean Span, Target Accuracy and False Negative) *Mean Span* is the number of digits recalled (measure of verbal memory). *Target Accuracy* is the number of target faces identified (measure of non-verbal memory). *False Negative* is the number of target faces incorrectly missed. α was set at .05 apriori. Analysis of the combined variables showed that there was a significant effect of *Age* on *Accuracy* (F_{wilks} (6, 114) = 3.35, p = .004, partial η^2 = .15, power = .93). As the overall test of the weighted linear composite was significant, each of the dependent variables was then considered separately.

There was a significant effect of *Age on Mean Span*, with older adults recalling fewer digits than the young adults (F(2, 58) = 4.96, p = .010, partial η^2 = .15, power = .79). To investigate group differences between *Age*, a series of post hoc analyses were conducted using *Tukey's HSD* with α = .05. Tukey's test was used, as it is a moderately conservative post hoc to control for familywise error rate over entire sets of pairwise comparisons (Keppel & Wickens, 2004). There was a significant difference between young and older adults, with older adults recalling fewer digits than young adults (Refer to Table 16 below). There were no significant differences between young and middle old adults or middle and older adults (Refer to Table 16 below).

Table 16

Mean Recognition for Span (Verbal) Target Accuracy, (Non-Verbal) and False Negative (Non Verbal) Broken Down by Young Old, Middle Old, and Older Adults

	Age Group		
	Young Old	Middle Old	Older Adults
Variable	*M*	*M*	*M*
	(sd)	*(sd)*	*(sd)*
Mean Span	7.37 [a]	6.85	6.08
	(1.24)	*(1.05)*	*(1.69)*
Target Accuracy	75.95	74.29	71.50
	(16.48)	*(15.76)*	*(15.90)*
False Negative	27.90 [a]	25.71	21.85
	(5.92)	*(4.77)*	*(5.80)*

NB: a - Young old different from older adults

However, there was no significant effect of *Age* on *Target Accuracy* ($F(2, 59) = .40$, $p = .671$, partial $\eta^2 = .01$, power = .11) (Refer to Table 16 above). There was a significant effect of *Age* on *False Negative*, with younger adults missing more targets than the older adults ($F(2, 58) = 6.10$, $p = .004$, partial $\eta^2 = .17$, power = .87). To investigate group differences between *Age,* a series of post hoc analyses were conducted using *Tukey's HSD* with $\alpha = .05$. There was a significant difference between young and older adults, with younger adults missing more targets than the young adults (Refer to Table 16 above). There were no significant differences between young and middle old adults or middle and older adults (Refer to Table 16 above). This result is intriguing but could indicate that the younger adults rushed through the task, or found the task to be trivial.

Latency. A ONEWAY between groups univariate ANOVA (Analysis of Variance) was also run to assess the effect of *Age* (Young Old (18-49), Middle Old (50-64), and Older Adults (65+)) on *Latency* (Latency to Locate Target Face). α was set at .05 aprori. It was found there was a significant effect of *Age* on *Latency*, with middle old and older adults taking longer to identify a target face than young adults ($F(2, 59) = 9.28$, $p < .001$. partial $\eta^2 = .24$, power = .97). To investigate group differences between *Age*, a series of post hoc analyses were conducted using *Tukey's HSD* with $\alpha = .05$. It was identified that there was a significant difference between young and older adults, with older adults taking longer to identify the target face than young adults. In addition, there was a significant difference between young and middle old adults, with middle old adults taking longer to identify the target face (Refer to Table 17 below). However, there was no significant difference between middle and older adults (Refer to Table 17 below).

Table 17

Mean Latency (ms) to Remember the Faces (Nonverbal Memory Measure) Broken Down by Young Old, Middle Old, and Older Adults

	Age Group		
Variable	Young Old *M* *(sd)*	Middle Old *M* *(sd)*	Older Adults *M* *(sd)*
Mean Latency to Remember Faces	1217[ab] *(343)*	1912 *(1013)*	2165 *(681)*

NB: a – Difference between young and older adults, b – Difference between young and middle old adults

Additional Analyses

To follow up on the latency results from Study 1, a ONEWAY between groups univariate ANOVA (Analysis of Variance) was run to assess the effect of *Age* (Young Old (18-49), Middle Old (50-64), and Older Adults (65+)) on *Latency*. α was set at .05 apriori.

However, there was no significant effect of *Age on Latency* ($F(2, 59) = 1.42$, $p = .248$, partial $\eta^2 = .05$, power = 29) (Refer to Table 18 below).

Table 18

Mean Latency (ms) on Digit Span Task Broken Down by Young Old, Middle Old, and Older Adults

	Age Group		
Variable	Young Old *M* *(sd)*	Middle Old *M* *(sd)*	Older Adults *M* *(sd)*
Mean Latency (Milliseconds)	7034 *(954)*	7321 *(979)*	7559 *(1058)*

Discussion

Decline in emotion recognition may provide insight into what is happening in the aging brain. From the research (e.g., Issacowitz et al., 2007), there is evidence for age related decline of emotion recognition. Therefore, one of the aims of the current study was to assess whether older adults decline on the recognition of emotion. In line with this argument, it was predicted that older adults would have significantly poorer performance than the younger cohorts on the emotion recognition task. This prediction was partially supported as the results of the current study provided some evidence of age related decline in the ability to recognise emotions.

It was found that there was an age related decline on anger recognition, with middle and older adults less accurate than younger adults. In addition, older adults were found to be significantly less accurate in the recognition of anger than middle old adults. This finding supports the research of Calder et al. (2003), McDowell et al. (1994), Mill et al. (2009),

Suzuki et al. (2007), the meta-analyses of Ruffman et al. (2008) and most of the studies identified by Issacowitz et al. (2007) who found older adults were significantly less accurate in the recognition of anger than younger adults. This finding suggests that older adults decline on the ability to recognise anger. As there is evidence of decline in verbal memory (as identified below), this might suggest that older adults initially encoded anger verbally and subsequently were unable to retrieve the representation. For example, an individual may have initially encoded the emotional state of anger as a verbal representation in memory. Consequently, subsequent verbal memory failure may have resulted in the inability to correctly identify the emotional state seen in the study phase.

However, it was identified that there was no effect of age on sadness recognition. This finding does not support the research of Calder et al. (2003), Moreno et al. (1993), Mill et al. (2009), Suzuki et al. (2007), the meta-analysis of Ruffman et al. (2008) and most of the studies identified by Issacowitz et al. (2007) who found older adults were significantly less accurate in the recognition of sadness than young adults. However, the lack of finding an age related decline in sadness recognition supports four studies identified by Issacowitz et al. (2007) who found older adults performed similarly to the younger adults. Moreover, it also partially supports the research of Issacowitz et al. (2007) who only identified age differences on the lexical task.

It was found that older adults had less accurate fear recognition than the middle old adults. However, older adults were not significantly less accurate than younger adults. This finding does not support Calder et al. (2003), McDowell et al. (1994), Mill et al. (2009), the meta-analysis by Ruffman et al. (2008) and most of the studies identified by Issacowitz et al. (2007) who found older adults had significantly less accurate recognition of fearful faces than younger adults. However, it partially supports Issacowitz et al. (2007), who found older

adults had significantly less accurate recognition of fearful faces than young and middle old adults.

Further, it was identified there was no significant age decline in contempt recognition. Although there is a paucity of literature on contempt, the current finding does not support Mill et al. (2009), who found a decline in recognition of contempt faces from the age of 61. As there are few studies that have assessed contempt recognition in an aging cohort, it is difficult to assess whether the lack of decline would be supported.

In addition, it was identified there was also no effect of age on disgust recognition. This finding is not surprising as there is evidence in the literature to suggest that disgust recognition remains preserved. The lack of decline supports Suzuki et al. (2007), the meta-analysis of Ruffman et al. (2008) and most of the studies identified by Issacowitz et al. (2007) who found older adults had similar or even more accurate disgust recognition than younger cohorts. However, this finding does not support Issacowitz et al. (2007), who found middle and older adults scored significantly lower on lexical and facial tasks. Moreover, it does not support Mill et al. (2009), who found the oldest age cohort (over the age of 61) were significantly less accurate in recognising disgust faces than younger cohorts (18-60).

Contrary to the majority of the literature identified earlier, there was an age related decline on surprise recognition. It was found older adults were significantly less accurate in recognising surprised faced than both younger and middle old adult cohorts. This suggests that surprise recognition may remain preserved from aging until later adulthood. This finding does not support the meta-analysis of Ruffman et al. (2008) and the studies identified by Issacowitz et al. (2007) who found no decline in surprise recognition with age.

In addition, it was identified that there was no effect of age on happiness recognition. This finding does not support Mill et al. (2007) and the meta-analysis of Ruffman et al. (2008) who found older adults were significantly less accurate in recognising happy faces

than younger adults. However, it supports McDowell et al. (1994) and the majority of studies identified by Issacowitz et al. (2007) who found older adults had similar recognition of happy faces to younger adults. This finding also partially supports Issacowitz et al.'s (2007) research that identified no age differences for recognition of happy faces. Isaccowitz et al. argues that ceiling effects may have confounded the data. However, the current study used a different set of stimuli and therefore this might suggest that happiness recognition may remain preserved.

There was also no evidence of age related decline in neutral recognition. This finding does not support McDowell et al. (1994) and one study identified by Issacowitz et al. (2007) who found older adults were less accurate in recognising neutral faces than younger adults. However, it partially supports Issacowitz et al. (2007)'s own research that identified an age effect on the lexical task.

From the findings of the current study, there is some evidence of decline in emotion recognition. It was identified that there was age related decline for recognition of surprise, with older adults less accurate than young and middle older adults. It was also found that older adults had less accurate recognition of fear than middle old adults. Moreover, there was some evidence of incipient decline in anger recognition, with younger and middle old adults less accurate than younger adults. This provides some indication that recognition of emotions may decline with age.

A further aim was to assess whether decline in emotion recognition could be attributed to change in verbal or non-verbal memory, as well as to assess whether age related cognitive decline is generalised or modular. From the literature (e.g., Ferris et al., 1980), there is some indication of age related decline in non-verbal memory. However, there is evidence from the previous study to suggest that verbal memory might remain preserved from the effects of aging. Therefore, it was also predicted that decline in emotion recognition

would be attributed to non-verbal rather than verbal memory which would provide support for dissociation of memory processing and modular decline.

Contrary to the hypothesis, it was found that there was an effect of age on verbal memory (span). However, there was only a significant difference between the young and older adults. These results suggest that verbal memory in the form of span decay only starts in the 60's. Decline in verbal memory may also reflect a misunderstanding of how people actually store and retrieve digits. The findings of the current study do not support the literature (e.g., Nilsson, 2003) that suggests tasks requiring the maintenance of information in short-term memory are likely to remain preserved. This finding is also contrary to the results obtained in the first study. This is likely to reflect variation in the samples used for the two studies. In the first study young adults had an average span of 6.23. In the current study, they had a span of 7.32. This could indicate a damaged cohort of younger participants in the first study. Alternatively, it might indicate that young adults in the current study were more engaged or found the task less trivial than the participants in the first study. As there is evidence of decline in verbal memory and in emotion recognition, this might suggest older adults encoded emotions verbally that were later unable to be retrieved. Although there is evidence of verbal memory and emotion recognition decline, future research should explicitly explore the relationship between the two variables, otherwise a decline in the two domains of cognition may occur but not be interlinked or mutually interdependent. Despite finding evidence of decline for span, older adults were not found to decline in target accuracy on the memory for faces task. On the basis of this finding, non-verbal memory might be independent of emotion recognition. The lack of finding an age effect on the memory for faces task does not support the research of Crook and Larrabee (1992), Ferris et al. (1980), Riege and Inman (1981) and Trahan et al. (1986) who found age related decline in non-verbal memory. Whilst there was no apparent decline in non-verbal memory in the form of the

memory for faces task in the presence of emotion decline, this finding does not exclude the possibility that other types of visual processing may not be breaking down as a result of cognitive decline in aging and this may be expressed in the form of decline in emotion recognition.

There was an effect of latency on the memory for faces task, with older adults taking longer to recognise a target face than younger adults. As accuracy on the memory for faces task remained intact in older adults and there was a decline in latency, this might suggest dissociation between accuracy and latency for nonverbal stimuli. To follow up from the first study, additional analysis was conducted to assess the effect of age on latency for span. Unlike in the previous study, it was identified that there were no differences between the cohorts on latency.

Overall Conclusions

The results provide evidence for an age related decline in emotion recognition. In particular, it was identified that older adults had significant decline for anger, sadness, and surprise. The finding of a decline in span suggests that decline in verbal memory may contribute to decline in emotion recognition. This might suggest that older adults initially encode emotions verbally and subsequently were unable to recall the representation. There was also some evidence that non-verbal memory may be independent of emotion recognition. As verbal memory was found to decline and non-verbal memory was found to remain intact, this provides evidence for dissociation of memory processing. In addition, this suggests that age related decline occurs in distinctive parts of the brain that may decline at different rates and provides some evidence for a modular decline. However, this finding needs to be interpreted with caution, as it is possible that the verbal and non-verbal measures were somewhat unbalanced in terms of task difficulty.

The finding that non-verbal memory in the form of memory for faces did not decline provides evidence for preservation of the visual system. However, this does not exclude the possibility that other types of visual processing may be breaking down as a result of cognitive decline in aging and that this may be expressed in the form of decline in emotion recognition. However, rather than decline for memory of the whole face, it is possible that older people may have difficulty in detecting specific features of the face (e.g., eyes and mouth). Therefore, in the next study, visual processing will be assessed using a novel task based on the Thatcher illusion. It is thought that this task will provide insight as to whether older adults have difficulty in detecting errors in features, which could be indicative of decline in the visual system. Another possibility is that decline in emotion recognition may reflect changes in areas involved in emotion processing. To test this idea, an emotion-valancing task will also be used to assess whether older adults perform differentially to younger adults. Subsequently, this may suggest decline in the emotion system.

Chapter 5

Study 3: Assessing differences in emotion and visual processing between young old, middle old and older Adults

From the previous chapter, there was evidence of age related decline in emotion recognition. In particular, older adults declined on the recognition of anger, surprise and fear, which is somewhat consistent with previous findings of others such as Calder et al. (2003), McDowell et al. (1994), Mill et al. (2009), Suzuki et al. (2007). It was also found that older adults had significant decline on digit span (verbal memory) and this suggests breakdown in verbal memory may contribute to decline in emotion recognition. Whilst there was no apparent decline in non-verbal memory in the form of the memory for faces task, this finding does not exclude the possibility of other types of visual processing breaking down and this may be expressed in the form of decline in emotion recognition. Based on the research (e.g., Andersen & Ni, 2008), there is some evidence to suggest that visual processing declines with age. To assess visual processing, a variation on the Margaret Thatcher illusion was used. It is argued that rather than processing faces as a whole, older adults may have difficulty in processing features of a face (e.g., eyes and mouth). This could suggest decline in the visual system, which may also be expressed in the form of decline in emotion recognition.

Another possibility is that there may be breakdown in the processing of emotional content. To assess emotion processing, an emotion valence-priming task was used. If areas of the brain associated with emotion processing are working, then there should be an effect of prime on the ability to locate congruently valence material. For example, an individual primed with positive material should be faster and more accurate to locate happy faces. However, if these areas have been affected by age, then there is likely to be less of a priming effect on the ability to identify congruently primed stimuli.

Visual Processing

Visual processing is thought also to be a key component in face processing. Decline of this subsystem is likely to also impact on the recognition of faces. It might be speculated that rather than encoding faces holistically, people use featural processing and process facial features in a piecemeal fashion. An early feature matching theory was proposed by Selfridge (1959) in his *Pandemonium*, a type of race model. Although Selfridge's model has been applied to letters, it is thought the idea could also be applied to features of the face. Refer to Figure 9 for a pictorial representation of Selfridge's model when applied to a facial feature, in particular the eye.

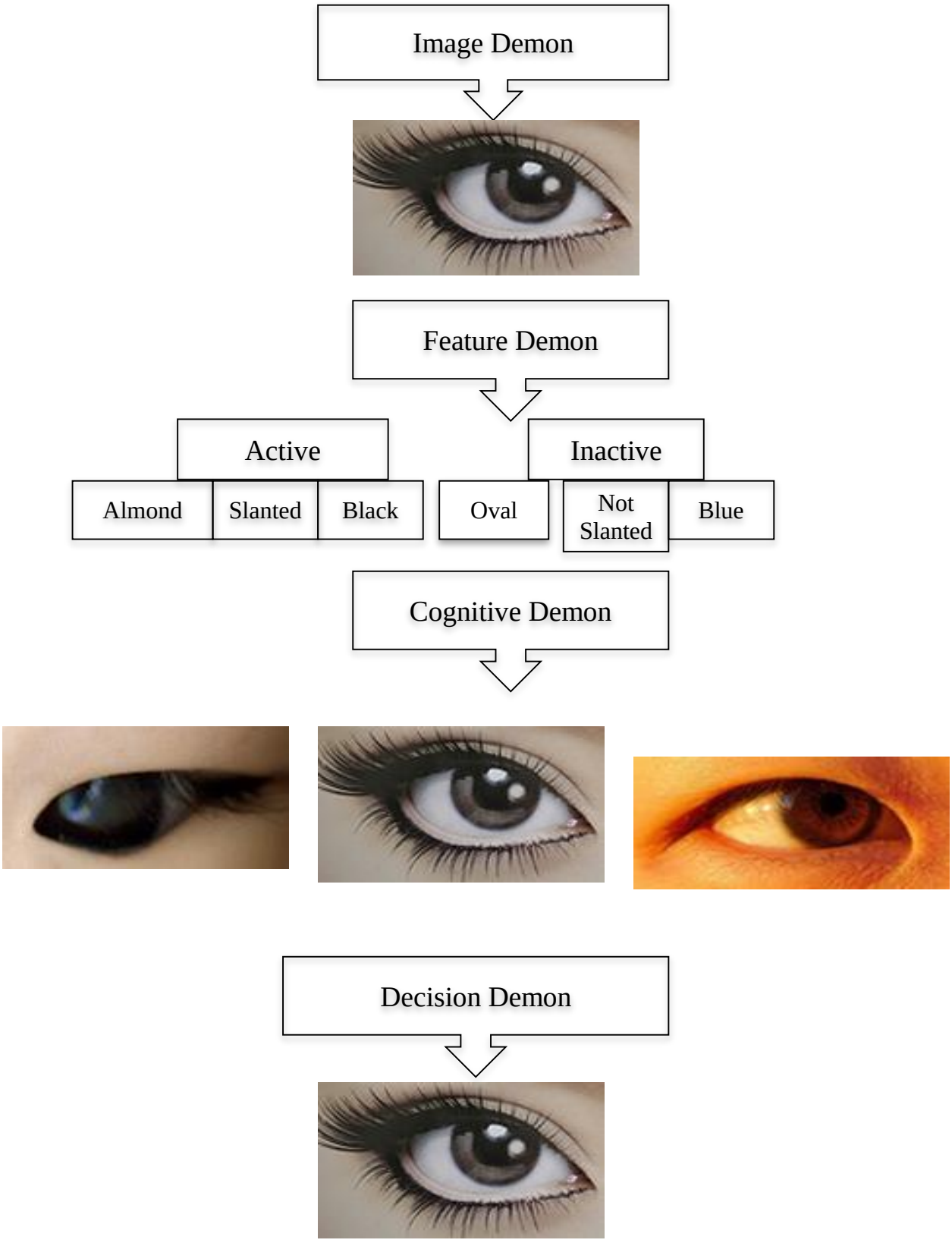

Figure 9. Application of Selfridge's Model to an Eye

A later model by Treisman (1986) posits that visual processing of objects might take the form of feature maps. Similar to Selfridge's (1959) model, Treisman's model has primarily been applied to letters; however, it was thought that the model might also be able to be applied to facial features. Refer to Figure 10 for a graphical representation of Treisman's model applied to Jack Nicholson's eye.

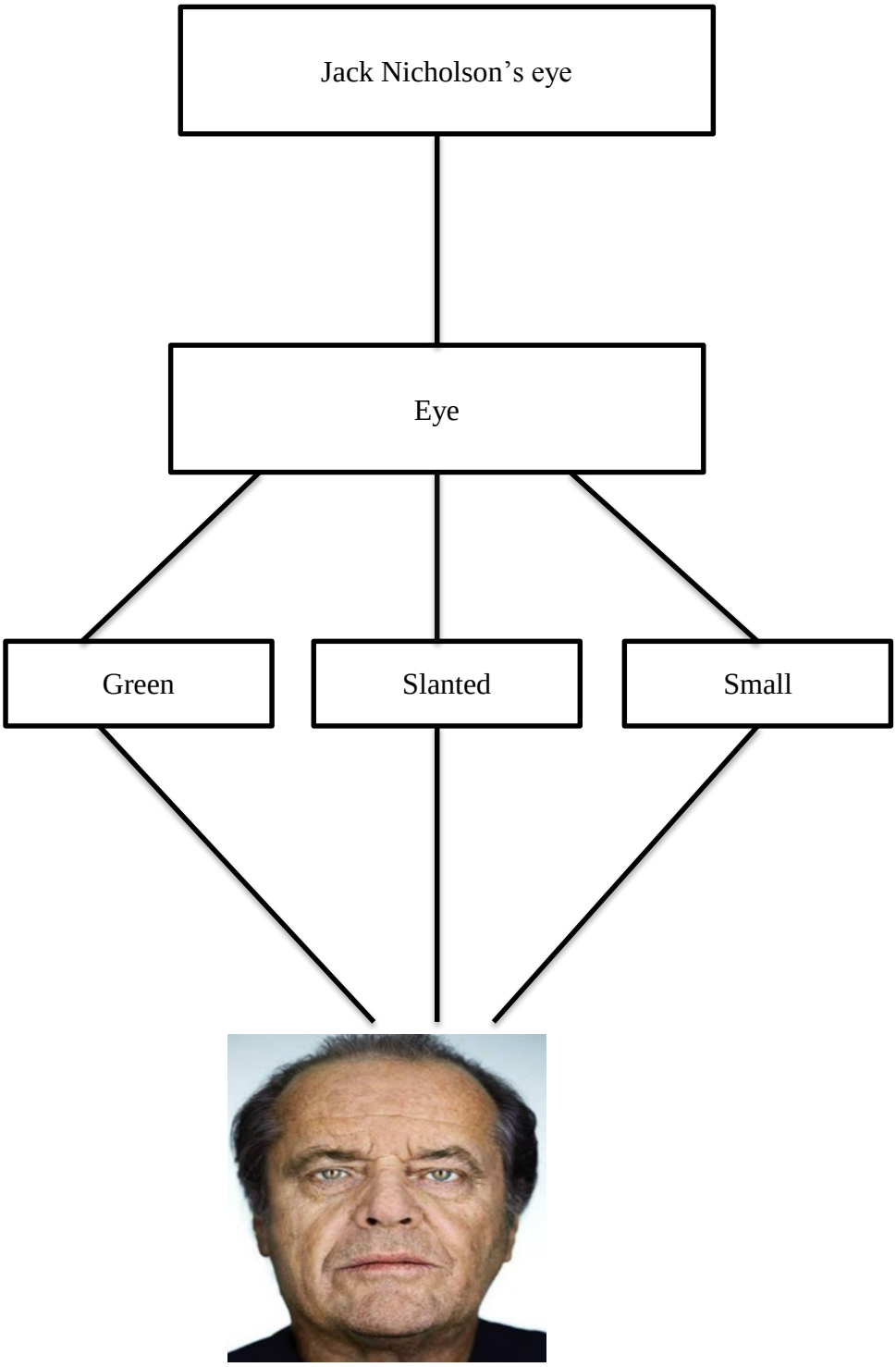

Figure 10. Interpretation of Jack Nicholson's Face using Feature Maps

A more modern understanding of how features are mapped to faces is provided in Carbon and Leder's (2005) description of the Thatcher illusion. They identify two types of processing involved in facial recognition: *holistic* and *featural* processing. *Holistic processing* is commonly defined as occurring when features are processed simultaneously as a whole. In addition they define *holistic processing* as "….processing of a holistic coherent Gestalt" (Carbon & Leder, 2005, p. 1117). *Featural processing* is defined as the processing of single features (Carbon & Leder, 2005).

Carbon and Leder (2005) argued that featural and holistic processing can be dissociated and in their study, they used a variation of the Thatcher illusion in their research due to the unique nature of the stimuli. The Thatcher illusion uses four pictures of the previous British prime minister. When Margaret Thatcher's face is upright, the face looks normal. However, when the eyes and mouth are inverted or "Thatcherised", the face looks grotesque due to the inversion of the features. If the face is inverted and the features are also inverted or "Thatcherised", with eyes and mouth correctly oriented in reference to the viewer, the face is commonly seen as unremarkable. Conversely, if a normal face is upside down, the integral features of the eyes and mouth are inverted in reference to the viewer and the overall face does not appear "coherent" (Carbon & Leder, 2005). Carbon and Leder also argue that the eyes and mouth are integral in facial recognition. Therefore, it is claimed that when the features are inverted, the facial expression portrayed is eliminated (Rakover, 1999). Carbon and Leder suggest that if featural processing is important for facial recognition, then the inverted Thatcherised faces should be recognised faster as the features are facing the same direction and no mental rotation of features is required. However, if holistic processing is important, then the original un-Thatcherised faces should be recognised faster as the face looks holistically coherent.

In Carbon and Leder's (2005) study, participants were shown "Thatcherised"

celebrity faces e.g., Julia Roberts as well as original, unmodified versions. Prior to the testing phase, participants were provided a familarisation phase where they were presented upright, original versions of the celebrities. On each trial in the testing phase, participants were asked "does the following picture show an original facial picture of forename and surname of one of the nine celebrities?'' (p. 1121). They were then shown an inverted face of one of the nine target celebrities presented as either an original or Thatcherised version.

Participants were told to answer yes only if they were sure the face was compatible with the name in the question, but also that the face was not Thatcherised. Carbon and Leder (2005) found at short presentation (26 ms), inverted Thatcherised faces were recognised faster than inverted original faces. They claimed that this was due to early featural processing. When the faces were presented at long presentation (200 ms), they found inverted original faces were recognised faster than inverted Thatcherised faces. Carbon and Leder claimed this was likely to be as a result of having more time available to process the holistic information of the face. It was also found when the faces were presented upright, normal faces were detected faster than faces that had been Thatcherised at both short (26 ms) and long (39 ms) presentations. On the basis of this finding, Carbon and Leder speculated that holistic information is available quicker for faces presented upright than for faces that are inverted.

In a previous study, Lewis (2001) found Thatcherised faces were detected faster than normal faces when presented upright (approximately 710 ms and 810 ms respectively) Moreover, processing time was comparable for normal and Thatcherised faces (approximately 970 ms and 990 ms respectively) when inverted. Although these findings contradict those of Carbon and Leder (2005), this is likely due to differences in presentation time of stimuli. Both of these studies used young adult participants and therefore it cannot be inferred whether older adults would process information in the same fashion. It is speculated

that older adults might be more likely to process the totality rather than the specific details of the face. Consequently, it is unlikely that they will detect errors in the specific features.

Emotion Processing

Carbon and Leder (2005) suggest the ability to process emotion cues in faces may reflect visual processing of the facial features. Another possibility is that structures responsible for emotion processing such as the limbic system (in particular, the amygdala) may decline with age. However, the research as to whether the amygdala declines with age is inconclusive. It has been found that the amygdala, though showing some reduction, may remain relatively preserved from aging when compared to other structures such as the prefrontal cortex (Grieve, Clark, Williams, Peduto, & Gordon, 2005). It has also been postulated that older adults may recruit other brain structures e.g., prefrontal and parietal areas in the processing of emotional material (Fischer et al., 2005; Gunning-Dixon et al., 2003; Iidaka et al., 2002). Therefore, older adults' processing of emotional content may be functionally different from younger adults.

Iidaka et al. (2002) assessed brain activation using fMRI whilst requiring participants to perform a valence task and found that older adults had significantly less activity in the left amygdala in response to negative valence faces compared to the younger adults. In addition, the older adults had significantly lower activity in the right parahippocampal, lingual and angular gyrus in perceiving positive valence faces. They also found that the parieto-occipital lobe showed an age related functional decline.

Gunning-Dixon et al. (2003) also assessing brain activation using fMRI whilst participants performed an emotion discrimination task, found that younger adults activated bilateral prefrontal and visual cortices when processing emotions. However, when younger adults were required to process the emotional facial expressions as part of the task, they also recruited right hemisphere temporo-limbic regions, in particular, the amygdala. In addition, it

was found that older adults had less limbic system activation than younger adults with greater activation in other areas. Compared to the young adults, older adults did not activate the temporo-limbic regions and instead recruited the anterior cingulate during face processing. Moreover, the older adults did not engage the right amygdala and nearby regions as did the young adults. Older adults also recruited the bilateral prefrontal and parietal regions when emotional aspects of the face were important to performance on the task. Since the older adults had activation in different areas compared to the young adults during the emotion discrimination task (e.g., frontal activation rather than limbic activation), this may suggest that that older adults process emotional content differently to younger adults (Gunning-Dixon et al., 2003).

Fischer et al. (2005) assessed brain activation using fMRI in participants who were passively viewing neutral and angry faces. They found that when perceiving neutral versus angry faces, younger adults had significantly higher right amygdala and hippocampus activation compared to the older adults. In comparison, older adults had higher right anterior-ventral insular cortex activation. The authors suggest that older adults are more likely to have higher cortical activation and lower subcortical activation when processing angry faces.

The previous studies indicate that older adults may have less activation of the amygdala than younger adults. However, Wright, Wedig, Williams, Rauch, and Albert (2006) found no significant difference between cohorts in activation of the amygdala in response to novel fearful stimuli compared to familiar neutral faces. In addition, they found that older adults had significantly less response in the fusiform gyru to both neutral and fearful faces compared to the younger adults. The authors acknowledge that the novelty of the stimuli may have interacted with the emotion and possibly could have been a salient factor in the activation of the amygdala. These studies suggest differential activation of different brain structures in the processing of emotional content. The study of neurological anatomy is

beyond the scope of the current study. However, if the structures responsible for emotion processing change with age, this may be reflected in decline in the processing of emotional content.

Priming studies (e.g., Carroll & Young, 2005) have found that stimuli consistent with current affective state are more likely to be responded to than stimuli that are incongruent or unrelated to affective state. For example, if a person is primed with positive stimuli, it is expected that the areas responsible for emotion processing will be activated. Consequently, they are likely to be faster and more accurate in the identification of stimuli that are congruent with that affective state. If there is age related decline in emotion processing, there is unlikely to be an effect of the prime on the ability to locate congruently valence material. In the current study, emotion processing will be assessed using valence-priming methodology.

Aims of Research

Decline in emotion recognition may provide insight into what is happening in the aging brain. From the research (e.g., Issacowitz et al., 2007) and the previous study, there is some evidence of age related decline of emotion recognition. Therefore, it was again predicted that older adults would have significantly poorer performance than the younger cohorts on the emotion recognition task.

There is some indication (e.g., Andersen & Ni, 2008) that visual processing may decline with age. To assess visual processing, a novel task based on the Thatcher illusion was used. It was hypothesised that older adults may adopt a holistic approach and process the features of the face as a whole. In processing the face as a whole, older adults may tend to make a judgement on the integrity of the whole without comparing each feature with its surrounds, effectively terminating processing of the face early. Consequently, when the

features are inverted, despite the inversion of the face, older adults are unable to detect errors in specific features.

An alternate model is that that structures responsible for emotion processing may be vulnerable to changes with age. This then might be reflected in decline in the processing of emotional content. It is thought that if an individuals are primed with a certain type of stimuli (e.g., negative words), they are likely to be more faster and more accurate to identify the same type of stimuli (e.g., negative faces) as the valence words should result in the activation of the emotion system (or semantic associative network). However, if there is no priming effect in the older cohort, then this may suggest evidence of decline in emotion processing. It was anticipated that the older adults would be unaffected by the prime. Consequently, they would be less accurate and slower to process both types of valence stimuli than younger adults.

A further aim was to assess whether age related cognitive decline is modular or generalised. For example, if there is decline in visual processing but emotion processing remained intact, this would provide evidence for a dissociation of process and that decline occurs differentially throughout the brain. This would be indicative of a modular decline. However, if there is decline in both visual processing and emotion processing, this might indicate an overall generalised degradation of cognitive functioning.

Method

Participants

A sample of 77 participants was recruited from South-Eastern Queensland to participate in the study. A purposive sampling technique was used. Although purposive sampling is not as effective as stratified random sampling and is not be representative of the

population, this technique is useful in gathering participants that share particular characteristics (Babbie, 2007). In this research, the particular characteristic of interest was independent living healthy older adults. The participants that comprised the young old sample were first year psychology students from a university that received course credit for participation in the research. The other participants were recruited from the local community. Screening of the data lead to the final sample of 73 comprising of 52 females (71.2%) and 21 males (28.8%). The age of the entire sample ranged from 19 to 82 years (M = 51.44, SD = 19.70). For highest education obtained, 50 (68.5%) participants nominated high school, 14 (19.2%) university, 6 (8.2%) nominated T.A.F.E/college and 3 nominated primary school (4.1%). From the participants, 36 (49.7%) were currently taking medication for illnesses e.g., high blood pressure, high cholesterol, diabetes, vascular problems. The other 37 participants (50.7%) were not currently taking medication. Chi-square analysis was also conducted to assess whether there was a difference in medical status by gender. However, this was not significant (χ^2 (1, n = 73) = .03, p = .854). Refer to Table 19 below.

Table 19

Cross-Tabulation of Medical Status x Gender

	Medical Status	
Gender	Taking medication	Were not taking medication
Males	10 (13.7%)	11 (15.7%)
Females	26 (35.6%)	26 (35.6%)

The participants were divided into three groups depending on age. The younger adults group (18-49) consisted of 26 participants with ages ranging from 19 to 47 (M = 27.58, SD = 9.14) with 20 (76.9%) females and 6 (23.1%) males. From the sample, 18 (69.2%)

participants nominated high school, 5 (19.2%) university, 2 (7.7%) nominated T.A.F.E/College and 1 (3.8%) nominated primary school as the highest level education obtained. Two of the participants (92.3%) were taking medication for illnesses e.g., high blood pressure, high cholesterol, diabetes, depression, vascular problems. Twenty-four (92.3%) participants were not taking medication.

The middle adults group (50 to 64) consisted of 24 participants with ages ranging from 50 to 64 (M = 58.25, SD = 4.74) with 17 (70.8%) females and 7 (29.2%) males. From the sample, 15 participants (62.5%) nominated high school, 5 (20.8%) university and 4 (16.7%) T.A.F.E/College as highest level of education obtained. Sixteen (66.7%) of the participants were taking medication for illnesses e.g., high blood pressure, high cholesterol, diabetes, depression, vascular problems. Eight participants (55.7%) were not taking medication.

The older adults group (65 and above) consisted of 23 participants with ages ranging from 65 to 82 (M = 71.30, SD = 3.87) with 15 (65.2%) females and 8 (34.8%) males. From the sample, 17 (73.9%) nominated high school, 4 (17.4%) university and 2 (8.7%) nominated primary school as highest level of education obtained. Eighteen (78.3%) of the participants were taking medication for illnesses e.g., high blood pressure, high cholesterol, diabetes, depression, vascular problems. Five (21.7%) participants were not taking medication.

Chi-square analysis was also conducted to assess whether there was a difference in medical status by age and was found to be significant ($\chi^2(2, n = 73) = 28.62, p < .001$). Refer to Table 20 below.

Table 20

Cross-Tabulation of Medical Status x Gender

	Medical Status	
Age	Taking medication	Were not taking medication
Young Old	2 (2.7%)	24 (32.9%)
Middle Old	16 (21.9%)	8 (11.0%)
Older Adults	18 (24.7%)	5 (6.8%)

Instruments

Emotion processing. A perceptual scanning task was used that was designed to assess emotion processing under a valence priming condition. Prior to the perceptual scan, participants were presented either a positive or negative valancing task.[11] A stem completion task was presented after the valence priming to ensure that participants had adequately processed the emotional material presented. Craik and Lockhart (1972) in their levels of processing model suggest that the deeper the material has been encoded, the more likely there will be a stronger, more persistent memory trace. During the stem completion task, participants were required to fill the last two letters of the first word that came to mind. Based on other research (e.g., Carroll & Young, 2005), it is thought that if the participants had received the positive prime, they would be faster and more accurate in the identification of positive facial stimuli (e.g., happy faces). If the participant had received the negative prime, then they would be faster and more accurate in the identification of negative stimuli (e.g., sad). Refer to Figure 11 for stimuli presented in perceptual scan task.

[11] Valence priming is when an individual is quicker in locating a target as a result of being primed with congruently valence material. For example, an individual is more likely to be quicker to find a negative face after being primed with negative material (Carroll & Young, 2005).

Figure 11. Stimuli from Perceptual Scan Task

In the priming phase, participants were presented either 15 positive or negative words. The words used in the current study had been previously evaluated (Meester, 2010). Refer to Appendix B for the list of words presented in the task. The words were presented for 2000 ms to ensure priming had occurred. A 500 ms blank time was presented between each word to allow the participant to reset prior to the presentation of the next word. In the stem completion task, participants were presented stems with the last two letters missing. Each of the stems was presented for 30000 ms before a timeout would occur and the next trial would be presented.

In the perceptual scan task, participants were presented 30 trials in which a face of either positive of negative emotion was presented in the centre of the screen. The stimuli were presented for 2000 ms to allow sufficient encoding of each face, followed by the presentation of a mask for 100 ms. A grid of nine faces was then shown in which participants were required to indicate either yes the face is in the grid or no the face is not present by pressing the appropriate keys as to whether the face that was shown is present. The task was self-paced.

Visual processing. A distorted facial recognition task based on the Margaret Thatcher illusion was used. The stimuli for this task consisted of four celebrities (Justin Timberlake, Alicia Silverstone, Jack Nicholson, and Helen Mirren) and four non-celebrity faces that were a young man, young woman, older man or older woman. For each stimuli there were six conditions: Not distorted right way up, eyes distorted right way up, eyes and mouth distorted

right way up, not distorted upside down, eyes distorted inverted eyes and mouth distorted inverted. Refer to Figure 12 for visual representation of stimuli.

Figure 12. Levels of Distortion for Famous Face

Participants were presented with 50 trials and were required to decide whether the faces were distorted or normal. On each trial, the face was presented in the centre of the screen with buttons labeled Press / for Distorted and Press – for Normal Responses underneath. Each of the faces was presented for 30000 ms before a timeout would occur and the next trial would be presented.

Span. To assess span, a digit span task was used which is designed to assess an individual's ability to keep information in short-term memory storage. The stimuli for this task were sets of numerical digits. The lowest number presented was three digits and the

highest that could be reached was 15 digits. It was expected that healthy individuals would recall 7 +/- 2 digits (Miller, 1994).

The task was formulated using a stair case method where once an estimate of response threshold was obtained; stimuli were never presented far from this threshold (Kantowitz et al., 2009). The first trial began with three digits presented and each ongoing presentation would subsequently increase depending on correct recall. The sequence of numbers would continue to increase if correct and drop back a digit if an incorrect sequence was recalled. The task would end either when the participant had reached maximum span performance or once 30 trials had been completed. The 30 trials ensured maximum span performance was obtained. An average of 5 trials for both accuracy and latency was taken to obtain span performance. The data was taken from trials 12-17 to reduce the potential of practice and fatigue effects which may have occurred during the start or end trials; thereby ensuring the most reliable measure of performance.

For each trial, the display time of the stimuli was 3000 ms to ensure sufficient encoding of the digits. A 2000 ms blank time was presented and then participants were provided 10000 ms to recall each trial of digits. Once 10000 ms had been reached, a timeout would occur and the next trial would be presented with one digit removed.

Emotion recognition. To assess emotion recognition, a face recognition task requiring participants to identify specific emotions (neutral, sad, happy angry, disgusted, contempt, surprise, fearful) was used. The images used in this task were of a young man, young woman, older man and older woman that were manipulated into the eight facial expressions (neutral, sad, happy, angry, disgusted, contempt, surprise, fearful) also using the computer program Crazy Talk 6 (Reallusion Inc, 2012). The software utilises a standard algorithm to distort a neutral image systematically to express emotional states by morphing facial features. To reduce the likelihood of cohort familiarity effects (e.g., young adults

performing better on younger faces), both young and old faces portraying the different facial expressions were used. Refer to Figure 13 for the emotions expressed by the young man used in the task.

Figure 13. Facial Expressions of Young Male Used in Emotion Recognition Task

Participants were presented with 100 trials of four different aged individuals (young man, young woman, elderly man or elderly woman) with one of the eight facial expressions (Neutral, sad, happy, angry, disgusted, contemptful, surprised, fearful). The stimuli were presented for 2000 ms to allow sufficient encoding of the face. A mask was then presented over the face so that the stimuli could not be seen. Participants were then provided 10000 ms to indicate which facial expression best matched the face presented on the screen. Once the face had been shown for 10000 ms, a time out would occur and the next face was presented. On each trial, the face was presented in the middle of the screen. A set of radio buttons

labelled with the eight expressions was presented for each face. On each trial, participants were instructed to indicate which description best fit the facial expression presented.

Experimental hardware. Each of the tasks was visually presented on a 15 inch Toshiba Satellite L540 laptop. The laptop had an Intel Core i5 2410M 2.3 GHz Processor running Windows 7 with 4GB of ram. The screen resolution was 32 bit and set at 1366 x 768 pixels.

Procedure

A potential issue that can arise in memory testing is that performance can be decremented when people are in unfamiliar locations (Russo et al., 1999). Therefore, middle and older adult participants were tested in situ (home or office locations) in order to obtain the most accurate performance. Although younger participants were tested at university, this is a familiar environment and therefore performance is unlikely to be decremented. For older people, a university environment could be daunting and therefore some of the differences in test performance might just be a function of the site of testing. The second argument is that older people may be less mobile and subsequently less inclined to travel than younger participants. Prior to administration, the tasks were counterbalanced to reduce the potential of order effects. Participants were verbally instructed to read the instructions on the laptop screen and indicate that they understood prior to the commencement of each task.

Emotion processing. Prior to the learning phase of the stem completion task, the following instructions were presented on the laptop screen:

'This experiment examines some basic cognitive functions involved in language and memory processing. The goal of this experiment is to see if these processes are related or not.

This experiment has two phases

1. *Vocabulary Phase*
2. *Test Phase*

Vocabulary Phase

The experiment begins with a vocabulary phase in which you will be given some words to study. These words vary in familiarity and your task is to try to remember them. Later you will be tested on your recognition memory.

Each word will appear briefly on the screen. Read it silently to yourself and try to remember it.

Press any key to continue…'

Prior to the stem completion task, the following instructions were presented on the laptop screen:

In this part of the task we will learn how many of the original words you remember. We are using a recognition paradigm to obtain the best estimate of your memory. For this task you will see all but the last two letters of a word presented on the screen. Fill in the last 2 letters to create the FIRST WORD THAT COMES TO MIND.

Your responses will be timed but don't rush and make typing errors.

If you can't think of a word type in xx and press enter to go to the next word.

Press any key to continue…'

Prior to the experimental phase of the priming task, the following instructions were presented on the laptop screen:

'In this part of the task we will learn how many of the original words you remember.

We are using a recognition paradigm to obtain the best estimate of your memory. For this task you will see all but the last two letters of a word presented on the screen. Fill in the last two letters to create the FIRST WORD THAT COMES TO MIND. Your responses will be timed but don't rush and make typing errors. If you can't think of a word type in XX and press enter to go to the net word. Press any key to continue.'

Prior to the perceptual scanning task, the following instructions were presented on the laptop screen:

'The purpose of this task is to see how quickly you can find a particular face amongst a grid of faces. First you will be shown one face in the centre of the screen. Your job is to try to remember that face, because later you will need to find it in a grid of nine faces. Sometimes the face will be present in the set, and other times it will not.

After you see the single face, you will see a blank screen and then you will be presented with a grid of faces. If you see the face in the grid press the / key. If the face is not present in the grid, press they z key'.

Visual processing. Prior to the commencement of the task, the following instructions were presented on the laptop screen:

'You are about to be presented with a series of images of peoples faces. Some of these images will have been deliberately distorted by the researcher. Your task is to identify which are the normal faces. Half of these faces are presented the right way up and the remainder are upside down. Press the "/" key on the left if the face is distorted, press the "-"on the right if the face is intact. Your responses are timed but don't rush. Make up your mind and then press the appropriate response key. Press any key to continue.'

Span. Prior to the commencement of the task, the following instructions were presented on the laptop screen:

'In this experiment we will investigate your short-term memory. You will be presented with "sets" of digits. Each new list is called a "repetition". Your task is to remember as many of the digits as you can in the sequence. You need to remember to press the enter key at the end of each set. Please wait for the instructions to appear on the screen asking you to enter the digits before typing the sequence. If you recall the sequence in correct order the number of digits will increase by one. If you make an error the number of digits will be

decreased by one. The experiment will end when you have completed 30 trials, or have exhibited stable recall'.

Emotion recognition. Upon commencement of the task, the following instructions were presented on the laptop screen:

'You are about to be shown some faces, you have to tell me which description matches the face shown, by pressing number 1 to 8 on the keyboard.

Press 1 – if the face looks neutral

Press 2 – if the face looks sad

Press 3 – if the face looks happy

Press 4 if the face looks angry

Press 5 – if the face looks disgusted

Press 6 – if the face shows contempt

Press 7 – if the face looks surprised

Press 8 – if the face looks fearful

Design

Emotion processing. A 3 x 2 between subjects factorial design was used. The independent and between subjects variables were *Age* (Young (18-49), Middle Old (50-64), and Older Adults (65 and above)) and *Valence Prime* (Positive vs. Negative Words). The dependent variables were *Identification of Target Faces* (Positive and Negative) and *Latency to Identify Target Faces* (Positive and Negative).

Visual processing. A 3 x 6 x 2 mixed factorial design was used. The independent and between subjects variable was *Age* (Young (18-49), Middle Old (50-64), and Older Adults (65 and above)). The independent variables *Distortion* (Not Distorted Right Way Up, Eyes Distorted Right Way Up, Eyes and Mouth Distorted Right Way Up, Not Distorted Upside Down, Eyes Distorted Inverted Eyes and Mouth Distorted Inverted) and *Fame* (Famous

Faces vs. Non Famous Faces) varied within subjects. The dependent variables were *Recognition* and *Latency*.

Span. A between subjects design was used. The independent variable was *Age* (Young (18-49), Middle Old (50-64), and Older Adults (65 and above)). The dependent variables were *Mean Span* and *Mean Latency*.

Emotion recognition. A between subjects design was used. The independent variable was *Age* (Young (18-49), Middle Old (50-64), and Older Adults (65 and above)). The dependent variables were *Recognition of Emotional State* (Neutral, Happy, Surprised, Anger, Sad, Fear, Disgust and Contempt) and *Latency to Recognise Emotional State* (Neutral, Happy, Surprised, Anger, Sad, Fear, Disgust and Contempt).

Results

Preliminary analysis

All data was screened and analysed using SPSS Statistics Version 21.0.

Emotion processing. Prior to analysis, the assumptions of MANOVA were tested. The assumption of sample size was met. Violations of normality were identified for both levels of the DVs using Kolmogorov-Smirnov ($p < .05$). However, MANOVA is robust to moderate violations of normality with larger sample sizes[12]. The data were linear. One multivariate outlier was removed from the final analysis. The data were not multicollinear. The assumption of homogeneity of covariance-matrices was met. No missing values were identified.

Visual processing. Prior to running the analysis, the assumptions of MANOVA were tested. The assumption of sample size was met. Violations of normality were identified for all levels of distortion for both DVs were identified using Kolmogorov-Smirnov ($p < .05$).

[12] Smallest cell size less than 20 (Tabachnick & Fidell, 2007).

However, MANOVA is robust to moderate violations of normality with larger sample sizes. The data were linear. One multivariate outlier was removed from the final analysis. The data were not multicollinear. Box's *M* was violated for *Latency* ($F(156, 12803) = 2.14$, $M = 444.50$, $p < .001$). As Box's *M* was violated, a more conservative *Pillai's criterion* was used to evaluate multivariate significance. No missing values were identified.

Span. Prior to running analyses, the assumptions of ANOVA were tested. Violations of normality for *Accuracy* were identified using Kolmogorov-Smirnov ($p < .05$). However, ANOVA is robust to violations of normality with larger sample sizes. Levene's Test indicated equal variances. No missing data was identified.

Emotion recognition. Prior to analysis, the assumptions of MANOVA were tested. The assumption of sample size was met. Violations of normality were identified for all levels of *Recognition of Emotional State* and *Latency to Recognise Emotional State* except for *Latency to Recognise Happiness Emotional State* using Kolmogorov-Smirnov ($p < .05$). However, MANOVA is able to compensate for violations in normality with larger sample sizes. Two multivariate outliers were removed. The data were not multicollinear. Box's *M* was violated for *Latency to Recognise Emotional State* ($F(72, 13385) = 1.84$, $M = 158.35$, $p < .001$). As Box's *M* was violated, a more conservative *Pillai's criterion* was used to interpret multivariate significance unless otherwise indicated. No missing values were identified.

Main Analysis

As there was an unbalanced design, *gender* and *education* were not included in the final analysis.

Emotion processing. A between groups factorial MANOVA (Multivariate Analysis of Variance) was conducted to assess the effect of *Age* (Young Old (18-49), Middle Old (50-64), and Older Adults (65 and above)) and *Valence Priming* (Positive Valence and Negative

Valence) on *Accuracy to Identify Target Faces* (Positive and Negative). α was set at .05 apriori.

There was no significant *Age* x *Valence Priming* interaction (F_{wilks} (4, 132) = .45, p = .770, partial η^2 = .01, power = .15). As there was no significant interaction, each of the main effects was considered. There was a significant effect of *Valence Priming* on *Identification of Target Faces* (F_{wilks} (2, 66) = .88, p = .014, partial η^2 = .12, power = .78). However, there was no significant effect of *Valence Priming* on *Positive Facial Targets* (F(1, 67) = 3.13, p = .081, partial η^2 = .05, power = .42) or *Negative Facial Targets* (F(1, 67) = 1.18, p = .282, partial η^2 = .02, power = .19). In addition, there was no significant effect of *Age* (F_{wilks} (4, 132) = .75, p = .557, partial η^2 = .01, power = .10).

Latency. A between groups factorial MANOVA (Multivariate Analysis of Variance) was conducted to assess the effect of *Age* (Young Old (18-49), Middle Old (50-64), and Older Adults (65 and above)) and *Valence Priming* (Positive Valence and Negative Valence) on *Latency to Identify Target Faces* (Positive and Negative). α was set at .05 apriori.

There was no significant *Age* x *Valence Priming* interaction (F_{wilks} (4, 132) = .69, p = .602, partial η^2 = .02, power = .22). As there was no significant interaction, each of the main effects was considered. There was no significant main effect of *Valence Priming* on *Latency to Identify Target Faces* (F_{wilks} (2, 66) = .33, p = .72, partial η^2 = .01, power = .10).

However, there was a significant main effect of *Age* (F_{wilks} (4, 132) = 2.89 p = .025, partial η^2 = .080, power approaching 1.00). Analysis of the additional dependent variables separately, showed there was an effect of *Age* on *Latency to Identify Negative Facial Targets*, with older adults taking longer to identify negative facial targets than younger adults (F(2, 67) = 3.40, p = .039, partial η^2 = .09, power = .62). To investigate group differences between *Age*, a series of post hoc analyses were conducted using *Tukey's HSD* with α = .05. Tukey's test was used, as it is a moderately conservative post hoc to control for familywise error rate

over entire sets of pairwise comparisons (Keppel & Wickens, 2004). There was a significant difference between younger and older adults, with older adults taking longer to identify negative target faces than young adults (Refer to Table 21 below). There were no significant differences between young and middle old adults or middle and older adults (Refer to Table 21 below).

In addition, there was a significant effect of *Age on Latency to Identify Positive Facial Targets,* with middle and older adults taking longer to identify positive facial targets than younger adults ($F(2, 67) = 3.95$, $p = .024$, partial $\eta^2 = .11$, power = .69) (Refer to Table 20 below). To investigate group differences between *Age,* a series of post hoc analyses were conducted using *Tukey's HSD* with $\alpha = .05$. There was a significant difference between the young and older adults, with the older adults taking longer to identify positive target faces than young adults (Refer to Table 21 below). In addition, there was a significant difference between the young and middle old adults, with the middle old taking longer to identify positive target faces than younger adults (Refer to Table 21 below). However, there was no difference between the middle and older adults (Refer to Table 21 below).

Table 21

Perceptual Scan Latency (ms) for Negative and Positive Facial Targets Presented by Age Group: Mean and Standard Deviations for Young Old, Middle Old, and Older Adults

	Age Group		
	Young Old	Middle Old	Older Adults
	M	*M*	*M*
	(sd)	*(sd)*	*(sd)*
Negative Faces	3863[a]	4172	4704
	(935)	*(*1041*)*	*(*1303*)*
Positive Faces	*3388* [ab]	*4088*	*4035*
	(618)	*(1038)*	*(1111)*

NB: a – Difference between young and older adults, b – Difference between young and middle old adults

Visual processing. A mixed factorial MANOVA (Multivariate Analysis of Variance) was conducted to assess the effect of *Age* (Young Old (18-49), Middle Old (50-64), and Older Adults (65+)), *Fame* (Famous vs. Non Famous) and *Distortion* (Not Distorted Right Way Up, Eyes Distorted Right Way Up, Eyes and Mouth Distorted Right Way Up, Not Distorted Upside Down, Eyes Distorted Upside Down, Eyes and Mouth Distorted Upside Down) on *Recognition*. α was set at .05 apriori. The assumption of sphericity for violated for *Distortion* and *Fame* x *Distortion* interaction. Therefore, more conservative degrees of freedom[13] were used.

There was no significant *Age* x *Fame* x *Distortion* interaction ($F_{pillai's}$ (7, 259) = 1.59, p = .117, partial η^2 = .11, power = .75). As the 3-way interaction was not significant, each of the two-way interactions was considered. There was no *Age* x *Fame* interaction ($F_{pillai's}$ (2, 70) = .40, p = .670, partial η^2 = .01, power = .11). There was also no significant *Fame* x

[13] A Geisser-Greenhouse correction was used as it is robust and there are more than 10 participants in each cell (Tabachnick & Fidell, 2007).

Distortion interaction ($F_{pillai's}$ (4, 259) = .89, p = .494, partial η^2 = .06, power = .30).

However, there was a significant *Age* x *Distortion* interaction ($F_{pillai's}$ (5, 259) = 2.84, p = .003, partial η^2 = .18, power = .97). To assess the influence of *Age* within levels of *Distortion*, a series of one-way ANOVAs were used. As *Age* did not vary with *Fame*, the effect of *Age* was examined collapsed across fame, forming 6 levels of *Distortion*. α was set at .05 apriori. There was no significant effect of *Age* on *Not Distorted Right Side Up Faces* (F(2, 70) = 2.53, p = .087). There was no significant effect of *Age* on *Eyes Distorted Right Side Up Faces* (F(2, 70) = 3.00, p = .056).

However, there was a significant effect of *Age* on *Eyes and Mouth Distorted Right Side Up Faces by Age*, with evidence of monotonic decline on this level of distortion (F(2, 70) = 15.31, p < .001). To investigate group differences between *Age*, a series of post hoc analyses were conducted using *Tukey's HSD* with α = .05. Tukey's test was used, as it is a moderately conservative post hoc to control for familywise error rate over entire sets of pairwise comparisons (Keppel & Wickens, 2004). There was a significant difference between younger and middle old adults, with middle old adults having less accurate recognition than younger adults (Refer to Table 22 below). There was also significant difference between younger and older adults, with older adults having less accurate recognition than older adults (Refer to Table 22 below). In addition, there was a significant difference between middle old and older adults, with older adults having less accurate recognition than middle older adults (Refer to Table 22 below). The overall pattern was of monotonic decline[14] with age with the most pronounced differences evident in the oldest group.

[14] A monotonic decline is a generalised linear decline.

Table 22

Accuracy of Judgments of Distorted Faces by Age Group: Mean and Standard Deviations for Young Old, Middle Old, and Older Adults

	Age Group		
Level of Distortion	Young Old *M* *(sd)*	Middle Old *M* *(sd)*	Older Adults *M* *(sd)*
Not Distorted Right Side Up	3.92 *(.18)*	3.63 *(.76)*	3.48 *(.98)*
Eyes Distorted Right Side Up	3.96 *(.14)*	3.81 *(.36)*	3.76 *(.37)*
Eyes and Mouth Distorted Right Side Up	*2.98* $_{ab}$ *(.69)*	2.29^{c} *(.91)*	1.65 *(.92)*
Not Distorted Upside Down	2.69 $_{ab}$ *(.90)*	2.02$_{c}$ *(.94)*	1.37 *(.94)*
Eyes Distorted Upside Down	3.88 *(.21)*	3.90 *(.25)*	3.70 *(.46)*
Eyes and Mouth Distorted Upside Down	3.17 *(.69)*	3.08 *(.94)*	2.71 *(.96)*

NB: a – Difference between young and older adults, b – Difference between young and middle old adults, c – Difference between middle and older adults

There was also a significant effect of *Age* on *Not Distorted Upside Down Faces*, with evidence of monotonic decline on this level of distortion ($F(2, 70) = 12.50$, $p < .001$). To investigate group differences between *Age,* a series of post hoc analyses were conducted using *Tukey's HSD* with $\alpha = .05$. There was a significant difference between younger and older adults, with older adults having less accurate recognition than the older adults (Refer to

Table 22 above). There was also a significant difference between younger and middle old adults, with middle old adults having less accurate recognition than younger adults (Refer to Table 22 above). In addition, there was a significant difference between middle and older adults, with older adults having less accurate recognition than middle older adults (Refer to Table 22 above). Again, the overall pattern was of monotonic decline with age with the most pronounced differences evident in the oldest group.

There was no significant effect of *Age* on *Eyes Distorted Upside Down Faces* ($F(2, 70) = 2.78$, $p = .069$). (Refer to Table 22 above). In addition, there was no significant effect of *Age* on *Eyes and Mouth Distorted Upside Down Faces* ($F(2, 70) = 1.85$, $p = .165$). (Refer to Table 22 above).

Significant interactions indicate that the main effects should be interpreted with caution. There was a significant main effect of *Distortion* ($F_{pillai's}$ (3, 195) = 102.71, $p < .001$, partial $\eta^2 = .89$, power approaching 1.00). It was identified that there was a significant difference between *Not Distorted Right Side Up and Eyes and Mouth Distorted Right Side Up,* with less accurate recognition for the *Eyes and Mouth Distorted Right Side Up* condition. There was also a significant difference between *Not Distorted Right Side Up* and *Not Distorted Upside Down,* with less accurate recognition for the *Not Distorted Right Side Up* condition. In addition, there was a significant difference between the *Not Distorted Right Side Up and Eyes and Mouth Upside Down,* with less accurate recognition for the *Eyes and Mouth Distorted Upside Down* condition.

There was a significant difference between the *Eyes Distorted Right Side Up* and *Eyes and Mouth Distorted Right Side Up,* with less accurate recognition for the *Eyes and Mouth Distorted Right Side Up* condition. There was also a significant difference between the *Eyes Distorted Right Side Up and Normal Upside Down,* with less accurate recognition for the *Normal Upside Down* condition. In addition, there was a significant difference between the

Normal Upside Down and *Eyes and Mouth Distorted Upside Down,* with less accurate recognition for the *Eyes and Mouth Distorted Upside Down* condition.

There was a significant difference between *Eyes and Mouth Distorted Right Side Up* and *Normal Upside Down,* with less accurate recognition for the *Normal Upside Down* condition. There was also a significant difference between *Eyes and Mouth Distorted Right Side Up* and *Eyes Distorted Upside Down,* with less accurate recognition for the *Eyes and Mouth Distorted Right Side Up* condition. In addition, there was a significant difference between *Eyes and Mouth Distorted Right Side Up* and *Eyes and Mouth Distorted Upside Down,* with less accurate recognition for the *Eyes and Mouth Distorted Right Side Up* condition.

It was also identified that there was a significant main effect of *Fame*, with famous faces recognised less accurately than non famous faces ($F_{pillai's}$ (1, 70) = 8.57, p = .005, partial η^2 = .11, power = .82). Famous faces were recognised less accurately than non famous faces.

In addition, there was a significant main effect of *Age* with evidence of monotonic decline on overall recognition (F(2, 70) = 29.42, p < .001, partial η^2 = .46, power approaching 1.00). To investigate group differences between *Age,* a series of post hoc analyses were conducted using *Tukey's HSD* with α = .05. There was a significant difference between young and older adults, with older adults having less accurate overall recognition than older adults. There was also a significant difference between young and middle old adults, with middle old adults having less accurate overall recognition than young adults. In addition, there was a significant difference between middle and older adults, with older adults having less accurate overall recognition than middle old adults. Again, the overall pattern was of monotonic decline with age with the most pronounced differences evident in the oldest group.

Latency. A mixed factorial MANOVA (Multivariate Analysis of Variance) was used to assess whether there was an effect of *Age* (Young Old (18-49), Middle Old (50-64), and Older Adults (65 and above)), *Fame* (Famous vs. Non Famous) and *Distortion* (Not Distorted Right Way Up, Eyes Distorted Right Way Up, Eyes and Mouth Distorted Right Way Up, Not Distorted Upside Down, Eyes Distorted Upside Down, Eyes and Mouth Distorted Upside Down) on *Latency. α* was set at .05 apriori. The assumption of sphericity for violated for *Distortion* and *Fame* x *Distortion* interaction. Therefore, more conservative degrees of freedom were used.

There was no significant *Age* x *Fame* x *Distortion* interaction ($F_{pillai's}$ (8, 277) = 1.16, p = .325, partial η^2 = .08, power = .59). As the 3-way interaction was not significant, each of the two-way interactions was considered. There was no significant *Age* x *Fame* interaction ($F_{pillai's}$ (2, 70) = 1.26, p = .291, partial η^2 = .04, power = .26). In addition, there was no significant *Age* x *Distortion* interaction ($F_{pillai's}$ (9, 301) = 1.42, p = .176, partial η^2 = .10, power = .70).

However, there was a significant *Fame* x *Distortion* interaction ($F_{pillai's}$ (4, 277) = 2.86, p = .020, partial η^2 = .18, power = .81. A series of paired *t*-tests were run to assess whether there was an effect of *Fame* within each level of *Distortion*. α was set at .05 was set at apriori. There was a significant effect of *Fame* on *Not Distorted Right Side Up*, with non famous faces having shorter latencies than famous faces (t(72) = 2.59, p = .012, partial $\eta^{2\,=}$ .08) (Refer to Table 23 below). There was no significant effect of *Fame* on *Eyes Distorted Right Side Up* (t(72) = 3.29, p = .743, partial $\eta^{2\,=}$ .00) (Refer to Table 23 below). In addition, there was no significant effect of *Fame* on *Eyes and Mouth Distorted Right Side Up* (t(72) = 1.94, p = .056, partial $\eta^{2\,=}$ .05) (Refer to Table 23 below).

Table 23

Latency in ms to Judgments Distorted Faces by Fame

	Fame	
Level of Distortion	Famous *M* *(sd)*	Non Famous *M* *(sd)*
Not Distorted Right Side Up	1932 *(1435)*	1567* *(964)*
Eyes Distorted Right Side Up	1540 *(783)*	1568 *(942)*
Eyes and Mouth Distorted Right Side Up	2622 *(1629)*	2280 *(1226)*
Not Distorted Upside Down	2067* *(1298)*	2537 *(1418)*
Eyes Distorted Upside Down	2102 (1267)	1831* *(1046)*
Eyes and Mouth Distorted Upside Down	2487 *(1628)*	2392 *(1289)*

NB: *- $p<.05$

However, there was a significant effect of *Fame* on *Normal Upside Down*, with famous faces having shorter latencies than non famous faces ($t(72) = 2.36$, $p = .021$, partial $\eta^2 = .07$) (Refer to Table 23 above). In addition, there was a significant effect of *Fame* on *Eyes Distorted Upside Down*, with non famous faces having shorter latencies than the famous faces ($t(72) = 2.51$, $p = .014$, partial $\eta^2 = .08$) (Refer to Table 23 above). However, there was no significant effect of *Fame* on *Eyes and Mouth Distorted Upside Down* ($t(72) = .56$, $p = .58$, partial $\eta^2 = .00$) (Refer to Table 23 above).

Significant interactions indicate that the main effects should be interpreted with

caution. There was no significant main effect of *Fame* ($F_{pillai's}$ (1, 70) = 2.35, p = .130, partial η^2 = .03, power = 33.

However, there was a significant main effect of *Distortion* ($F_{pillai's}$ (4, 301) = 19.19, p < .001, partial η^2 = .22, power approaching 1.00. It was identified that there was a significant difference between *Not Distorted Right Side Up* and *Eyes Distorted Right Side up,* with longer latencies for the *Not Distorted Right Side Up* condition. There was a significant difference between the *Not Distorted Right Side Up* and *Eyes and Mouth Distorted Right Side Up,* with longer latencies for the *Eyes Distorted Right Side Up* condition. There was also a difference between the *Not Distorted Right Side Up* and Eyes and *Mouth Distorted Upside Down,* with longer latencies for the *Not Distorted Right Side Up* condition.

There was also a significant difference between the *Eyes Distorted Right Side Up* and *Eyes and Mouth Distorted Right Side Up,* with longer latencies for the *Eyes and Mouth Distorted Right Side Up* condition. There was a significant difference between *Eyes Distorted Right Side Up* and *Not Distorted Upside Down,* with longer latencies for the *Not Distorted Upside Down* condition. There was also a significant difference between *Eyes Distorted Right Side Up* and *Eyes Distorted Upside Down,* with longer latencies for the *Eyes Distorted Upside Down* condition. In addition, there was a significant difference between *Eyes Distorted Right Side Up* and *Eyes and Distorted Upside Down,* with longer latencies for the *Eyes and Mouth Distorted Upside Down* condition.

There was a significant difference between *Eyes and Mouth Distorted Right Side Up* and *Eyes Distorted Upside Down,* with longer latencies for the *Eyes Distorted Right Side Up* condition. In addition, there was a significant difference between *Not Distorted Upside Down* and *Eyes Distorted Upside Down,* with longer latencies for the *Not Distorted Upside Down* condition.

There was also a significant main effect of *Age,* with older adults having significantly

longer latencies than young adults ($F(2, 70) = 5.29$, $p = .007$, partial $\eta^2 = .13$, power = .82). To investigate group differences between *Age,* a series of post hoc analyses were conducted using *Tukey's HSD* with $\alpha = .05$. It was identified that there was a significant difference between young and older adults, with older adults having significantly longer overall latencies than younger adults. However, there were no significant differences in latency between the young and old or middle and older adults.

Span. A ONEWAY between groups univariate ANOVA (Analysis of Variance) was run to assess the effect of *Age* (Young Old (18-49), Middle Old (50-64), and Older Adults (65+)) on *Mean Span.* α was set at .05 apriori. There was a significant effect of *Age* on *Mean Span,* with older adults recalling fewer digits than young adults ($F(2, 70) = 6.99$, $p = .002$, partial $\eta^2 = .17$, power = .92). To investigate group differences between *Age,* a series of post hoc analyses were conducted using *Tukey's HSD* with $\alpha = .05$. Tukey's test was used, as it is a moderately conservative post hoc to control for familywise error rate over entire sets of pairwise comparisons (Keppel & Wickens, 2004). There was a significant difference between young old and older adults, with older adults recalling fewer digits (Refer to Table 24 below). However, there were no significant differences between middle and older adults or young and middle old adults (Refer to Table 24 below).

Table 24

Mean Span and Latency (ms) by Age Group: Young Old, Middle Old, and Older Adults

	Age Group		
Span and Latency Variables	Young Old *M* *(sd)*	Middle Old *M* *(sd)*	Older Adults *M* *(sd)*
Mean Span	7.32[a] *(.95)*	6.58 *(1.33)*	6.09 *(.95)*
Mean Latency	6230 *(1289)*	6544 *(1297)*	6750 *(1272)*

NB: a - Young old different from older adults

Latency. A ONEWAY between groups univariate ANOVA (Analysis of Variance) was also run to assess the effect of *Age* (Young Old (18-49), Middle Old (50-64), and Older Adults (65+)) on *Mean Latency***.** α was set at .05 apriori. However, there was no significant effect of *Age* on *Mean Latency* (*2*(2, 70) = 1.02, p = .365, partial η^2 = .03, power = .22) (Refer to Table 24 above).

Emotion recognition. A ONEWAY between groups MANOVA (Multivariate Analysis of Variance was conducted to assess the effect of *Age* (Young Old (18-49), Middle Old (50-64), and Older Adults (65+)) on *Recognition of Emotional State* (Neutral, Happy, Surprised, Anger, Sad, Fear, Disgust and Contempt). α was set at .05 apriori. Analysis of the combined variables showed that there was a significant effect of *Age* on *Recognition of Emotional State* (F_{wilks} (16, 126) = 2.54, p = .002, partial η^2 = .24, power = 99).

As the overall test of the weighted linear composite was significant, each of the dependent variables was then considered separately. Analysis of the dependent variables separately, showed that there was no significant effect of *Age on Recognition of Neutral Emotional State* (*F*(2, 70) = .87, p = .423, partial η^2 = .02, power = .19) (Refer to Table 25 below). There was also no significant effect of *Age on Recognition of Happiness Emotional*

State ($F(2, 70) = 2.12$, $p = .127$, partial $\eta^2 = .06$, power = .42) (Refer to Table 25 below). In addition, there was no significant effect of *Recognition of Surprised Emotional State* on *Age* ($F(2, 70) = 1.11$, $p = .336$, partial $\eta^2 = .03$, power = .24) (Refer to Table 25 below).

However, there was a significant effect of *Age on Recognition of Angry Emotional State,* with middle old and older adults recognising fewer angry faces than young adults ($F(2, 70) = 15.32$, $p < .001$, partial $\eta^2 = .31$, power = approaching 1.00). To investigate group differences between *Age,* a series of post hoc analyses were conducted using *Tukey's HSD* with $\alpha = .05$. Tukey's test was used, as it is a moderately conservative post hoc to control for familywise error rate over entire sets of pairwise comparisons (Keppel & Wickens, 2004). There was a significant difference between young and older adults, with older adults recognising fewer angry faces than young adults (Refer to Table 25 below). There was also a significant difference between young and middle old adults, with middle old adults recognising fewer angry faces than younger adults (Refer to Table 25 below). However, there were no significant differences between the middle and older adults (Refer to Table 25 below).

Table 25

Mean Recognition for Eight Facial Expressions Broken Down by Young Old, Middle Old, and Older Adults

	Age Group		
Facial Expressions	Young Old *M* *(sd)*	Middle Old *M* *(sd)*	Older Adults *M* *(sd)*
Neutral	.61 *(.17)*	.56 *(.17)*	.62 *(.16)*
Happy	.50 *(.16)*	.49 *(.19)*	.40 *(.16)*
Surprised	.38 *(.13)*	.39 *(.18)*	.32 *(.18)*
Anger	$.40_{ab}$ *(.16)*	.24 *(.15)*	.20 *(.11)*
Sad	.30 *(.17)*	.26 *(.13)*	.27 *(.20)*
Fear	.09 *(.08)*	.12 *(.08)*	.08 *(.09)*
Disgust	.14 *(.11)*	.15 *(.12)*	.12 *(.12)*
Contempt	.20 *(.18)*	.18 *(.11)*	.18 (.15)

NB: a – Difference between young and older adults, b – Difference between young and middle old adults

However, there was no significant effect *of Age* on *Recognition of Sad Emotional State* ($F(2, 70) = .55$, $p = .58$, partial $\eta^2 = .02$, power = .18) (Refer to Table 25 above). There was no significant effect of *Age* on *Recognition of Fearful Emotional State* ($F(2, 70) = 1.79$, $p = .175$, partial $\eta^2 = .05$, power = .36) (Refer to Table 25 above). There was also no

significant effect of *Age* on *Recognition of Disgust Emotional State* ($F(2, 70) = .41$, $p = .665$, partial $\eta^2 = .01$, power = .11). (Refer to Table 25 above). In addition, there was no significant effect of *Age* on *Recognition of Contempt Emotional State* ($F(2, 70) = .93$, $p = .933$, partial $\eta^2 = .00$, power = .06) (Refer to Table 25 above).

Latency. A ONEWAY between groups MANOVA (Multivariate Analysis of Variance was used to examine whether there was an effect of *Age* (Young Old (18-49), Middle Old (50-64), and Older Adults (65+)) on *Latency to Recognise Emotional State*. α was set at .05 apriori. Analysis of the combined variables showed that there was a significant effect of *Age* on *Latency to Recognise Emotional State* ($F_{pillai's}$ (16, 128) = 2.12, $p = .009$, partial $\eta^2 = .22$, power = 97).

As the overall test of the weighted linear composite was significant, each of the dependent variables was then considered separately. There was a significant effect of *Age* on *Latency to Recognise Neutral Emotional State*, with middle and older adults taking longer to recognise neutral faces than young adults ($F(2, 70) = 6.56$, $p = .002$, partial $\eta^2 = .16$, power = .90). To investigate group differences between *Age*, a series of post hoc analyses were conducted using *Tukey's HSD* with $\alpha = .05$. There was a significant difference between younger and older adults, with older adults taking longer to recognise neutral faces than young adults (Refer to Table 26 below). There was also a significant difference between young and middle old adults, with middle old adults taking longer to recognise neutral faces than young adults (Refer to Table 26 below). However, there was no significant difference between middle and older adults (Refer to Table 26 below).

Table 26

Mean Latency (ms) for Eight Facial Expressions Broken Down by Young Old, Middle Old, and Older Adults

	Age Group		
Facial Expressions	Young Old *M* *(sd)*	Middle Old *M* *(sd)*	Older Adults *M* *(sd)*
Neutral	20821_{ab} *(8423)*	31669 *(13080)*	29610 *(12052)*
Happy	27831_{ab} *(880)*	38439 *(13816)*	37561 *(13489)*
Surprise	25001 *(8526)*	37075_{b} *(15058)*	32100 *(8366)*
Anger	24846_{ab} *(10578)*	36959 (10716)	38978 *(15104)*
Sad	16363_{ab} *(6313)*	23103 *(9173)*	23898 *(9128)*
Fear	23235_{ab} *(5081)*	33296 *(10843)*	32099 *(8366)*
Disgust	37596_{b} *(12301)*	47684 (14640)	47240 (15587)
Contempt	28039_{ab} (8999)	36989 (10186)	37297 (13069)

NB: a – Difference between young and older adults, b – Difference between young and middle old adults

There also was a significant effect of *Age* on *Latency to Recognise Happiness Emotional State*, with middle and older adults taking longer to recognise happy faces than young adults ($F(2, 70) = 5.98$, $p = .004$, partial $\eta^2 = .15$, power = .86). To investigate group differences between *Age*, a series of post hoc analyses were conducted using *Tukey's HSD*

with $\alpha = .05$. There was a significant difference between young and older adults, with older adults taking longer to recognise happy faces than young adults (Refer to Table 26 above). There was also a significant difference between young and middle old adults, with middle old taking longer to recognise happy faces than young adults (Refer to Table 26 above). However, there was no significant difference between middle old and older adults (Refer to Table 26 above).

In addition, there was a significant effect of *Age* on *Latency to Recognise Surprised Emotional State,* with middle old adults taking longer to recognise surprised faces than young adults ($F(2, 70) = 7.54$, $p = .001$, partial $\eta^2 = 18$, power = .94). To investigate group differences between *Age,* a series of post hoc analyses were conducted using *Tukey's HSD* with $\alpha = .05$. There was a significant difference between young and middle old adults, with middle old taking longer to recognise surprised faces than young adults (Refer to Table 26 above). However, there were no significant differences between young and older adults or middle old and older adults (Refer to Table 26 above).

In addition, there was a significant effect of *Age* on *Latency to Recognise Angry Emotional State,* with middle and older adults taking longer to recognise angry faces than young adults ($F(2, 70) = 9.78$, $p < .001$, partial $\eta^2 = .22$, power = .98). To investigate group differences between *Age,* a series of post hoc analyses were conducted using *Tukey's HSD* with $\alpha = .05$. There was a significant difference between young and older adults, with older adults taking longer to recognise angry faces than the young adults (Refer to Table 26 above). There was also a significant difference between young and middle old adults, with middle old taking longer to recognise angry faces than the young adults (Refer to Table 26 above). However, there was no significant difference between middle old and older adults (Refer to Table 26 above).

It was also identified that there was a significant effect of *Age* on *Latency to Identify Sadness Emotional State*, with middle and older adults taking longer to recognise sad faces than young adults ($F(2, 70) = 6.30$, $p = .002$, partial $\eta^2 = .15$, power = .89). To investigate group differences between *Age,* a series of post hoc analyses were conducted using *Tukey's HSD* with $\alpha = .05$. There was a significant difference between young and older adults, with older adults taking longer to recognise sad faces than young adults (Refer to Table 26 above). There was also a significant difference between young and middle old adults, with middle old taking longer to recognise sad faces than the young adults (Refer to Table 26 above). However, there were no significant differences between middle old and older adults (Refer to Table 26 above).

There was a significant effect of *Age on Latency to Recognise Fearful Emotional State*, with middle and older adults taking longer to recognise fearful faces than young adults ($F(2, 70) = 7.23$, $p = .001$, partial $\eta^2 = .18$, power = .93). To investigate group differences between *Age,* a series of post hoc analyses were conducted using *Tukey's HSD* with $\alpha = .05$. There was a significant difference between young and older adults, with older adults taking longer to recognise fearful faces than the young adults (Refer to Table 26 above). There was also a significant difference between young and middle old, with middle old taking longer to recognise fearful faces than young adults (Refer to Table 26 above). However, there was no significant difference between middle old and older adults (Refer to Table 26 above).

It was also identified there was a significant effect of *Age* on *Latency to Recognise Disgust Emotional State*, with middle old adults taking longer to recognise disgust faces than young adults ($F(2, 70) = 4.06$, $p = .021$, partial $\eta^2 = .10$, power = .70). To investigate group differences between *Age,* a series of post hoc analyses were conducted using *Tukey's HSD* with $\alpha = .05$. There was also a significant difference between young and middle old adults, with middle old taking longer to recognise disgusted faces than young adults (Refer to Table

26 above). However, there were no significant differences between the young and older adults or middle old and older adults (Refer to Table 26 above).

In addition, there was a significant effect of *Age* on *Latency to Recognise Contempt Emotional State*, with middle and older adults taking longer to recognise contempt faces than young adults ($F(2, 70) = 5.94$, $p = .004$, partial $\eta^2 = .15$, power = .87). To investigate group differences between *Age,* a series of post hoc analyses were conducted using *Tukey's HSD* with $\alpha = .05$. There was a significant difference between young and older adults, with the older adults taking longer to recognise contempt faces than young adults (Refer to Table 26 above). There was also a significant difference between young and middle old adults, with middle old taking longer to recognise contempt faces than the young adults (Refer to Table 26 above). However, there was no significant difference between middle old and older adults. (Refer to Table 26 above).

Discussion

Although decline in non-verbal memory (memory for faces) was not observed in the previous study, this did not exclude the possibility that other types of visual processing are breaking down, which may be expressed in the form of decline in emotion recognition. Consequently, it was investigated whether decline in emotion recognition is related to changes in the processing of visual stimuli. To assess visual processing, a novel task based on the Thatcher illusion was used. When the face is upright and the features are inverted, the face looks grotesque. When the face is upside down and features are inverted or "Thatcherised", the face loses its coherency, but the eyes and features seem correctly oriented in regards to the viewer (Carbon & Leder, 2005). It was speculated that older adults might adopt a holistic approach and process the features of the face as a whole. In processing the face as a whole they may be prone to make a judgement on the integrity of the whole without

comparing each feature with its surrounds, effectively terminating processing of the face early. Consequently, when the features are inverted despite the inversion of the face, they are unable to detect errors in specific features.

Failure to recognise emotions may also represent breakdown in the processing of emotional content. Therefore, the integrity of emotion processing by utilising a valence-priming task was investigated. Participants were primed with either positive or negative words and then required to search a matrix of faces for a specific stimulus (face). Based on the research of Carroll and Young (2005), it was thought that where emotion processing is intact, there should be an increase in accuracy and decrease in search latency for emotions that have been previously primed. However, if age related decline has occurred in the emotion processing centres of the brain, then their accuracy and search latencies will be unaffected by emotional priming.

Based on the research (e.g., Anderson & Ni, 2008), it was anticipated that visual processing would decline with age. This was supported, as there was a significant age by distortion interaction on the distorted facial recognition task. When the interaction was split by distortion, it was found that both middle and older adults were significantly less accurate than younger adults when faces were upright and eyes and mouth distorted. This suggests that middle and older adults are processing overall cues, as they are unable to detect the errors in individual features. In addition, middle and older adults were significantly less accurate for undistorted upside down faces than younger adults. This again suggests processing of overall cues, as they were unable to detect that the individual features were undistorted. If older adults are processing the totality of the face, then they might process all features as distorted and therefore the face must also be distorted. This is consistent with making sense of the features as a whole rather than processing the elements.

Overall, there is some evidence to suggest that middle and older adults are more likely to process overall cues rather than processing individual features. This finding parallels the finding of gist studies (e.g., which suggest that older people process the whole rather than the specific detail) although these have not been applied to feature integration. Middle and older adults were found to be less accurate than the younger adults when features were congruent, which suggests that they have difficulty in processing specifics of the stimulus. This may indicate some evidence of a breakdown in feature processing in the visual system with age. In addition, as this task was capable of detecting incipient decline, this suggests there is some utility in its use as a screening tool for detection of cognitive decline.

Older adults also had significantly longer latencies for the task than the younger adults. The increase in latencies was not specific to any levels of distortion. This suggests that older adults were persisting at the task, or found the task difficult. A decrease in accuracy and increase in latency provides some support for generalised slowing. It is possible that this is a consequence of amyloid β build-up. This increase in amyloid β build-up may then result in disturbances of neural network activity or neuronal death (Cramer et al., 2012; Palop & Mucke, 2010).

An alternate model is that that structures responsible for emotion processing might be vulnerable to changes with age. This then might be reflected in decline in the processing of emotional content. Research e.g., Carroll and Young (2005) posit that if affective priming is working then a face should be located faster and more accurately after congruent material is presented. However, if age related decline has occurred in the emotion processing centres of the brain, then there is unlikely to be a priming effect. It was anticipated that the older adults would be unaffected by the prime. Consequently, they would be less accurate and slower to identify both types of valence stimuli than younger adults.

From the perceptual scanning task, it was found there was no interaction between priming and age on identification of target. In addition, no effect of priming was observed. It is possible that the words provided in the valence priming condition were not strongly valanced enough to activate the emotion system (or semantic associative network). Future research could consider having the emotional words rated for strength of emotionality by another set of participants prior to the experiment. In addition, there was no effect of age on identification of target. This suggests that processing of emotional stimuli remains preserved with age.

There was no interaction between age and priming on latency of search. In addition, no effect of priming was observed, which may suggest that stronger primes are required. However, there was a significant effect of age. It was found that middle and older adults took significantly longer than younger adults in the location of positive target faces. In addition, older adults were found to take significantly longer in the location of negative faces than young adults. This could indicate middle and older adults were unable to disengage from the negative faces on the grid. Alternatively, it could indicate that they were strategically fixating on the positive faces. The latter argument might provide evidence for a positivity bias in the older cohorts. Another possibility is that since there was no accompanying decline in accuracy, older adults are compensating by using alternative pathways to retrieve information. The *cognitive reserve hypothesis* claims that as direct pathways to knowledge become impaired, older adults are able to compensate by using redundant pathways (Stern, 2009). Subsequently, the use of alternative pathways results in higher latencies in the retrieval of information. As there was an increase in latency but no accompanying decrease in accuracy, this also provides some evidence of dissociation between accuracy and latency.

Span again was assessed using a digit span task. The results found that older adults recalled significantly fewer digits than the younger adults. It is possible that the older adults

are making semantic associations from numbers they have previously stored in memory. As there is only a small decrease in span (average of 1 digit), this finding suggests that decline in span is not as severe compared to other domains of cognition. In addition, there was no significant effect of age on latency.

To follow up from the previous study, emotion recognition was assessed. It was found there was a significant effect of age on emotion recognition. However, older adults were found to be less accurate only on the recognition of anger. This finding differs from the results obtained in the previous study where age related decline was also found in the recognition of fear and surprise. These two results could indicate that age related decline is more strongly associated with anger, than with fear and surprise. On the other hand sampling variation may be responsible for the differing results and further study is needed. In addition the instrument used may not have been sufficiently sensitive to change and other instruments should also be considered in further research. The decline in anger recognition is consistent with the research identified in the previous chapter of Calder et al. (2003), McDowell et al. (1994), Mill et al. (2009), Suzuki et al. (2007), in meta-analyses conducted by Ruffman et al. (2008) and studies identified by Issacowitz et al. (2007), which identified age related decline for recognition of anger. For all other emotions, older adults performed equivalently to the younger adults. This could indicate that emotion recognition is unlikely to provide insight into what is occurring in the aging brain.

There was an effect of emotional state on latency of identification. It was identified that older adults took significantly longer than young adults on recognition of all emotional states except for disgust. In addition, middle older adults were significantly slower than the young adults on all emotional states. This finding again provides support for the *cognitive reserve hypothesis, which* claims that as direct pathways to knowledge become impaired older adults can compensate by using redundant pathways (Stern, 2009). The use of indirect

pathways results in longer to retrieve information. Moreover, there is evidence of dissociation between accuracy and latency on the emotion recognition task.

A further aim was to assess whether age related cognitive decline is modular or generalised. As decline was found in visual processing but emotion processing remained intact, this provides evidence for a dissociation of process and that decline occurs differentially throughout the brain.

Overall Conclusions

From this study, there was little evidence of age related decline in the recognition of emotion. There was also no evidence of age related decline on identification of facial targets. This provides some evidence that emotion processing remains preserved.

However, there was evidence of age related decline in visual processing. There was some indication that both middle old and older adults are more likely to process the totality of the stimuli. This may suggest an age related change in processing in that when individuals get older, they are more likely to process the whole, rather than the specific detail. An alternative explanation of the apparent decline in the processing of specific visual details may be the indirect consequence of an age related change in memory. Decline in the ability to process the specific details of the object may result in remembering only the general idea or the "gist". In the next study, it was investigated whether older adults remember the gist over specific detail.

Chapter 6

Study 4: Differences in Ability to Recall Gist and Specific Detail between Young, Middle and Older Adults

In the previous study, it was found that older adults were more likely than younger adults to process overall cues rather than specific features of stimuli. Although the tendency to process the totality was found in relation to visual processing, this may indicate that cognitive decline in older adults is reflected by decline in the ability to process the fine details of specific stimuli. Memory is also an area of functioning where older adults may have difficulty in processing in specific detail. An alternative explanation of the apparent decline in the processing of specific visual details may be the indirect consequence of an age related change in memory. Decline in the ability to process the specific details of the object may result in remembering only the general, abstract detail or the "gist".

Guerin, Robbins, Gilmore, and Schachter (2012) argued that gist errors might occur during the encoding process in that the details were not encoded in the first place. In addition, Guerin et al. (2012) posited that gist errors might also occur from the memory trace degrading over time. Consequently, it may be argued that as a result of improper encoding and/or decline in the memory trace, older individuals are unable to retrieve specific information and can only remember the general idea, or the gist. For example, if a red umbrella with white polka dots was the target stimulus, the older adult may only be able to remember that it was a red umbrella, or simply an umbrella.

Another potential explanation for the apparent decline in memory for specific detail might not be the failure to encode the detail as suggested by Guerin et al. (2012), but rather that older adults have an increased tendency to encode non-selectively due to poor inhibitory mechanisms. There was some indication of age related decline in the executive functioning

component of response inhibition identified in the first study. Similar to the framework of Hasher and Packs discussed in the first study (Chapter 2), older adults are unlikely to be able to control the type of information entering working memory. As a consequence of encoding non-selectively, older adults are likely to have rich or cluttered semantic networks, so when new items are stored there is little to distinguish them from the many similar instances that were previously stored. Moreover, the common features reinforce the existing memory trace with unique features being less well stored and more vulnerable to decline. Consequently, a gist or general representation is therefore more likely to be stored. Hence, older adults make more gist errors than younger adults as a function of storing generally over a broad set of units. A specific episodic trace or item specific representation is more likely to be encoded when the trace is distinctive and a new association is stored over a new set of units. As older adults are also unable to selectively filter irrelevant information, they may also have a higher susceptibility to selecting a prototypical member of a set. Refer to Figure 14 below for a visual representation of this model.

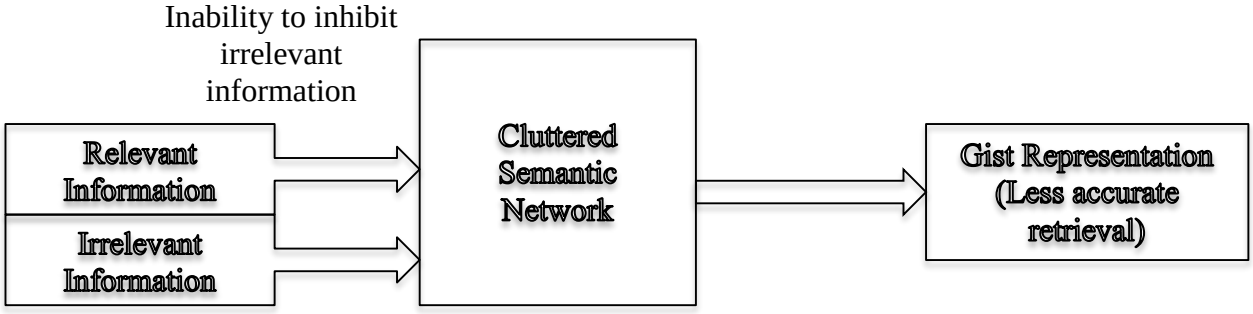

Figure 14. Representation of Older Adults Inability to Inhibit Irrelevant Information

The Deese/Roediger-McDermott (DRM; Roediger & McDermott, 1995) is a paradigm used that provides a measure of gist-based errors. In this paradigm, participants are required to study a list of semantically associated words *(e.g., bed, rest, awake)* during the

learning phase. During the test phase, participants are presented words that were previously studied, unrelated studied and non-studied words along with a critical non-studied lure word that converges on the theme presented in the test phase (e.g., sleep). This parallels the prototypical member of the set. Roediger and McDermott (1995) found that individuals were more likely to falsely recognise the non-studied critical lures than the unstudied unrelated lures (e.g., snow). A possible explanation is that after studying semantic associates a gist representation of the list is encoded. Then by presenting related non-studied lures at test, this causes an illusionary feeling of familiarity that the word had been seen previously, increasing the likelihood of gist-based errors (Budson et al., 2006). Alternatively, this may also suggest that people are likely to identify a stimulus that is similar to the typical members of the set.

Budson, Daffner, Desikan, and Schachter (2000), using a modified version of the DRM (Roediger & McDermott, 1995), assessed whether the repetition of the paradigm would increase the likelihood of gist-based errors, particularly in individuals with probable Alzheimer's disease. Participants were required to study 6 15-word lists with a theme on which the associates converged. During the test phase participants were presented with 36 words in which 6 of the words were related lures, 18 studied words and 12 unrelated unstudied lures. The study-test procedure was repeated 5 times. Budson et al. (2000) found that younger and older adults had similar levels of true and false recognition after repeated trials. In addition, it was found that whilst probable Alzheimer's disease participants' true recognition increased, their recognition was still significantly lower than the younger and older adults. In addition, although their true recognition was found to increase, their false recognition also increased to be significantly higher than the older adults after the 5 trials. Signal detection analysis of item specific recollection identified that initially older adults and individuals with probable Alzheimer's disease performed similarly on their ability to distinguish studied items versus lures. However, with repeated trials older adults were

increasingly able to distinguish between studied items and related lures, whereas Alzheimer's dementia participants remained at chance.

Budson et al. (2000) suggest the fact that Alzheimer's disease participants have similar deficits to individuals with Korsakoff amnesia may indicate that even individuals with mild to moderate Alzheimer's disease have dysfunction of frontal networks contributing an inability to suppress semantic gist. It is speculated that this type of reasoning is flawed in that even though they may share similar behavioural patterns, they are both different types of disorders and therefore are unlikely to have the same patterns of neuroanatomical decline. Budson et al. also suggest individuals with Alzheimer's disease may have source memory confusion and decline in semantic memory. In addition to these possible mechanisms, they suggest impaired episodic memory may be due to medial temporal dysfunction alone. However, despite the attempt to link to neuroanatomical correlates, they did not use any equipment to assess neuroanatomical functioning and therefore have no evidence to support this line of argument. The focus of this study is not on neuroanatomical correlates but to assess whether older adults perform differently to younger adults and so may provide some indication of cognitive decline. The findings of Budson et al. (2000) that older adults performed similarly to younger adults is contrary to the notion of any decline. However, the sample size in this study was limited in that there were only 13 participants in the younger adult group, 15 in the older adult group and 12 with probable Alzheimer's disease. Therefore, the lack of differences between the younger and older adults may indicate inadequate power in the sample. In addition, it may be argued that repeated repetitions of stimuli create the opportunity for increased performance on the task. However, it is possible that the repeating presentations of stimuli induce potential artifacts and increase the likelihood for intrusion errors.

In a later study, Budson, Sullivan, Daffner, and Schachter (2003) using a task similar to the DRM, with the addition of phonological, hybrid and mixed word lists, found that older adults had significantly corrected higher false recognition on all list types than the younger adults. Older adults also had significantly higher corrected false recognition for all list types when compared to the individuals with Alzheimer's disease. It was also found younger and older adults also had similar levels of corrected true recognition for all list types. In addition, it was found that the Alzheimer's disease individuals had higher levels of relative false recognition[15] when compared to older adults. The authors speculate that the Alzheimer's disease individuals' greater false recognition compared to true recognition was due to an inability to use item specific memory, which forced them to rely on gist processes. The finding of older adults performing similarly to the younger on true recognition is again contrary of any notion of decline. Therefore, it might be that sometimes a general representation can result in a correct response via partial mapping.

Budson and other authors argue that item specific and gist are two specific memory systems. This line of argument suggests a modular type framework in that "item specific memory" declines earlier than "gist memory". They argue as consequence of decline in item specific memory, older adults are forced to rely on gist for memory decisions. However, it is speculated that it is unlikely there are discrete systems that store "item specific" and "gist" traces. As discussed earlier, it is thought that gist errors occur as a result of storing over a rich or cluttered memory network with common features being less well stored and more vulnerable to decline. In addition, a specific or "item specific" trace is more likely to be encoded with the trace as distinctive and a new association is stored over a new set of units. Therefore, it is speculated that gist errors occur as a consequence of storing generally, rather than relying on "gist memory".

[15] Budson et al. (2003) suggests relative recognition (false recognition divided by true recognition) provides a measure of how likely participants respond old to a related lure (due to gist) versus a studied word (either item specific or gist). Therefore, relative recognition is thought to provide a measure of the tendency to rely on gist over item-specific.

Using a different paradigm to the DRM, Guerin et al. (2012) implemented a visual memory task with a younger adult sample. In the first experiment, participants were shown coloured photographs divided into 4 conditions. In the baseline target condition, the target was shown along with two unrelated items. In the baseline foil condition, all 3 items were unrelated to the studied items. In the single related item condition one of the pictures was related to the study item, with the other 2 unrelated but no target picture presented. In the target and related item condition, the target was presented to the adjacent item with the third item unrelated to the studied item. On each trial, participants were presented with three pictures. Two of the pictures were related to one another because they were exemplars of the same category and shared similar characteristics. Participants were also assessed using an MRI eye tracking system. In the first experiment Guerin et al. (2012) found that participants made more gist-based errors in the single related item condition. However, when the target was presented in the target and related condition there was a significant decrease in gist errors.

In the second experiment, participants were presented with a condition of two items that were related to the study item and a third item that was unrelated. Guerin et al. (2012) found that participants had no reduction in gist-based errors in the two related items condition. Similar to the first experiment, there was a significant reduction in gist errors in the target and related condition when participants had the benefit of the originally presented study item. The authors acknowledge that even though gist errors declined in the target and related conditions, they were not entirely eliminated.

Although Guerin (2012) did not use a suitable comparison group, it was speculated that if younger adults still make gist errors when provided retrieval cues, then it is likely that older adults will also make gist errors in the presence of the target. In the current study, a pictures task was used where retrieval cues (target picture) were provided in each block.

Based on initial pilot testing for the current study, it was found that younger adults still made gist errors in that they identified a similar item when the target was presented. Therefore, it is speculated that in an aging brain, older adults will be more likely to make gist errors on a picture recognition task even when retrieval cues are provided.

In an earlier study, Budson, Todman, and Schachter (2006) using a different paradigm to the DRM, investigated memory in older adults and individuals with Alzheimer's disease using a categorising pictures task. Participants were divided into two groups: One group received standard instructions requiring where they were instructed to say if they had seen the picture previously. The other group received modified instructions requiring them to recall whether they had seen that picture before or if it was one that belongs in the same picture category. The authors suggest that the modification in instructions "…. would reflect the development and use of gist memory alone, rather than reflecting gist memory opposed by item specific recollection" (p. 14). As discussed earlier, it is unlikely there are discrete systems for "gist memory" and "item specific memory".

Budson et al. (2006) found both groups endorsed greater number of items in the modified condition. However, in the modified condition, participants with Alzheimer's disease made fewer endorsements of related lures than older adults when the data was corrected for false alarms. In addition, it was also found that Alzheimer's disease participants had a higher liberal responding bias and falsely endorsed an equal number of somewhat related and truly unrelated items. Therefore, Budson et al. (2006) argued that the increase in liberal responding was due to an inability to inhibit responses rather than a diffuse gist representation that would have been indicated by higher endorsement of very or somewhat related items.

Budson et al. (2006) suggests that gist memory decline might result from decline in the infero-lateral temporal lobes and/or medial temporal lobes. Again, they give no evidence

to support this argument. They also suggested that poor attention might be responsible for decline. This is likely to be as a result of impairment of the attentional control system that focuses attention, which they suggest is reliant on the frontal lobes. Budson et al. argue based on other research, that formation and encoding of gist is reliant on automatic activation processes in which concepts that are semantically related are activated. This process is thought to remain intact in Alzheimer's disease. However, if attentional control is impaired, then they may have not been able to attend adequately to the stimuli during the encoding process. Although participants with Alzheimer's disease were found to be significantly less accurate than the older adults, there was no younger sample to assess whether older adults would have decline compared to a younger population. Therefore, it is possible that older adults may show some level of decline, albeit not to the level of severity in individuals with Alzheimer's disease.

Hudon et al. (2006) as part of their research used the DRM (Roediger & McDermott, 1995) with a sample of participants with mild cognitive impairment, Alzheimer's disease and older adult controls. During the study phase, participants were provided 12 lists of 12 semantically associated words. For each list there was a critical non-presented word on which the 12 words converged (e.g., for the critical non studied lure cold, the study words were winter, hot, ice, snow etc.). Participants were presented 36 studied items and 36 non-studied items in the recognition phase. The 36 non-studied items consisted of 12 critical lures, 12 weakly related lures and 12 unrelated lures. The targets and lures were divided into two sets used on two recognition trials. Each set contained 18 target words as well as 6 critical, 6 weakly related and 6 unrelated lures.

Hudon et al. (2006) found that older adults and participants with mild cognitive impairment had similar levels of true and false recognition. In addition, participants with Alzheimer's disease had significantly lower levels of both type of recognition when

compared to both older adults and participants with mild cognitive impairment. However, it was found that all groups had similar levels of corrected true recognition of studied items when compared to the corrected recognition false recognition of related lures. Moreover, signal detection analysis comparing hits vs. critical lures found that sensitivity was at chance level for all groups. This suggests that all groups had evidence of intrusion errors in that they were unable to distinguish critical lures from the studied items. Hudon et al. (2006) acknowledge that the task may have been too demanding and consequently this result is likely to indicate floor effects in the data.

In the second experiment, a new sample of participants were administered a narrative task consisting of 128 high frequency and familiar words with 23 macropropositions and 24 micropropositions. During the study phase, participants were informed they had 3 minutes to read and memorize the content. Following the study phase, the text was hidden and participants were required to freely recall the study word-for-word. An immediate recall task was administered, followed by delayed recall task, which was performed 10 minutes later. Hudon et al. (2006) found that the Alzheimer's disease participants were the most impaired on both types of recall for both immediate and delayed conditions. The mild cognitive impairment participants were also significantly impaired on the text recall task, albeit not to the severity of the participants with Alzheimer's disease. An intriguing finding was that memory for micropropositions (detailed information) and macropropositions (gist) were impaired to the same degree for the participants with mild cognitive impairment and Alzheimer's disease. As expected, all groups including older adults had a higher proportion of recall for the macropropositions than micropropositions suggesting they were better at remembering the general idea over specific detail.

As there was only a significant difference between the mild cognitive impairment participants and older adults on text recall, this may suggest that memory decline is also

dependent on the difficulty of the task. The text recall task requiring specific recall of propositions is likely to have required a higher level of cognitive resources (e.g., working memory and attention) than the DRM which requires the recognition of semantic associates (Roediger & McDermott, 1995). This may indicate that working memory and attentional capacity are more impaired than semantic processing in early stages of cognitive decline. A surprising aspect of Hudon et al.'s (2006) study was the lack of a suitable comparison group and therefore the study is unable to provide an indication as to whether older adults would make more gist-based errors when compared to younger adults. However, there is some indication that older people remember the general idea over specific detail.

Aims of Research

One of the aims of the research was to assess whether older people are more likely to make gist errors than the younger cohort. If older adults are more likely to remember the general idea or gist, this may provide evidence that there is some level of cognitive decline. From the literature (e.g., Hudon et al., 2006), there was some indication that older adults are better at remembering the general idea over specific detail. Therefore, it was predicted that older adults were more likely to make gist errors than younger adults.

A further aim was to assess whether age related decline is modular or generalised. If there is age related decline for specific detail but memory for the general idea remains intact, this could be indicative of modular decline, if there are separate stores for "gist" and "item specific". As previously mentioned, memory for the general idea is more likely to be a consequence of storing generally. Therefore, if decline for memory of specific material is observed but that memory for the general idea specific remains intact, this is likely to be more indicative of generalised decline. However, if decline for verbal material is observed but non-verbal remains intact, this would be indicative of dissociation of verbal and non-verbal representations and provide support for modular decline with increasing age.

Method

Participants

A sample of 70 participants was recruited from South-Eastern Queensland to participate in the study. A purposive sampling technique was used. Although purposive sampling is not as effective as stratified random sampling and is not be representative of the population, this technique is useful in gathering participants that share particular characteristics (Babbie, 2007). In this research, the particular characteristic of interest was independent living healthy older adults. The young adults sample was comprised of first year students from a university and received course credit for participation in the research. The other participants were recruited from the local community in South-Eastern Queensland. Screening of the data lead to the final sample of 66 comprising of 49 females (74.2%) and 17 males (25.8%). The age of the entire sample ranged from 18 to 86 years (M = 50.06, SD = 21.52). For highest education obtained, 42 (63.6%) participants nominated high school, 17 (25.8%) university, 5 (7.6%) nominated T.A.F.E/college and 2 nominated primary school (3.0%). From the participants, 35 (53.0%) were currently taking medication for illnesses e.g., high blood pressure, high cholesterol, diabetes, vascular problems. The other 31 participants (47.0%) were not currently taking medication. Chi-square analysis was conducted to assess whether there was a difference in medical status by gender. However, this was not significant (χ^2 (1, n = 66) = 2.89, p = .089). Refer to Table 27 below.

Table 27

Cross-Tabulation of Medical Status x Gender

Gender	Medical Status	
	Taking medication	Were not taking medication
Males	11 (16.7%)	6 (9.1%)
Females	20 (30.3%)	29 (43.9%)

The participants were divided into three groups depending on age. The younger adults group (18-49) consisted of 24 participants with ages ranging from 18 to 46 (*M* = 24.13, *SD* = 8.13) with 22 (91.7%) females and 2 (8.3%) males. From the sample, 19 (79.2%) participants nominated high school, 3 (12.5%) university, 1 (4.2%) nominated primary school and 1 (4.2%) nominated T.A.F.E/College as the highest level education obtained. One of the participants (4.2%) was taking medication for illnesses e.g., high blood pressure, high cholesterol, diabetes, depression, vascular problems. Twenty-three (95.8%) participants were not taking medication.

The middle adults group (50 to 64) consisted of 20 participants with ages ranging from 50 to 64 (*M* = 57.40, *SD* = 5.13) with 14 (70.0%) females and 6 (30.0%) males. From the sample, 9 participants (45.0%) nominated university, 8 (40.0%) high school, and 3 (15.0%) T.A.F.E/College as highest level of education obtained. Eleven (52.4%) of the participants were taking medication for illnesses e.g., high blood pressure, high cholesterol, diabetes, depression, vascular problems. Nine (45.0%) participants were not taking medication.

The older adults group (65 and above) consisted of 22 participants with ages ranging from 65 to 86 (*M* = 71.68, *SD* = 5.33) with 13 (59.1%) females and 9 (40.9%) males. From

the sample, 15 (68.2%) nominated high school, 5 (22.7%) university, 1 (4.5%) nominated T.A.F.E/College and 1 (4.5%) nominated primary school as highest level of education obtained. Twenty-one (95.5%) of the participants were taking medication for illnesses e.g., high blood pressure, high cholesterol, diabetes, depression, vascular problems. One (4.5%) participant was not taking medication.

Chi-square analysis was also conducted to assess whether there was a difference in medical status by age and was found to be significant ($\chi^2(2, n = 66) = 34.78, p < .001$). Refer to Table 28 below.

Table 28

Cross-Tabulation of Medical Status x Gender

	Medical Status	
Age	Taking medication	Were not taking medication
Young Old	1 (1.5%)	23 (65.7%)
Middle Old	10 (15.2%)	10 (15.2%)
Older Adults	20 (5.7%)	2 (64.5%)

Instruments

Non-verbal gist. A picture recognition task was used as a measure of non-verbal gist. The stimuli for the initial learning phase consisted of pictorial exemplars from 27 categories (e.g., a robin was an exemplar for the bird category). The categories consisted of balls, teddy bears, beds, birds, butterflies, cars, cats, chairs, clocks, dogs, fans, fish, picture frames, eyeglasses, grapes, houses, insects, pens, shoes, socks, staplers, teapots, tissue boxes, tomatoes, trees, t-shirts and umbrellas.

In the learning phase, each of the 27 exemplars was presented individually on the screen. The exemplars were presented for 2000 ms to ensure sufficient encoding of each picture. After each stimulus had been shown on the screen, a 100 ms mask and 500 ms blank time were provided to allow the participant to reset prior to the presentation of the next exemplar.

A number search task was presented prior to the experimental phase. In the number search task, participants were presented blocks of numbers and were required to count the number of 7s. This was designed to provide a longer time period between learning and experimental phases and make the task more difficult.

In the experimental phase, participants were presented 27 trials. On each trial, 4 pictures were presented. One of the items was the initial exemplar from the learning phase. The second item was close to the exemplar in semantic similarity, usually in colour, or another type of the object (e.g., a different type of clock). The third item was functionally related to the original item. (e.g., an hour glass similar to a clock but still tells time). The final item was unrelated (e.g., a vase). Participants were required to select the item that was seen in the learning phase. The task was self-paced. Refer to Figure 15 for a visual presentation of one of the trials presented in the experimental phase.

Figure 15. Example of Test Phase (Target, Semantically Related Item, Functionally Related Item and Unrelated Item) Presented in Visual Gist Task

Verbal gist. A variation of the Deese/Roediger-McDermott (DRM; Roediger & McDermott, 1995) was used as a measure of non-verbal gist. The words used in this task were also adapted from Roediger and McDermott, as they had been found to be capable of detecting gist errors in a younger cohort. Refer to Appendix C for a list of words used in the task.

In the learning phase, 12 words were presented individually on the screen. They were also read aloud by the program. Six of the words presented were related to the non-studied critical lure and six were unrelated. Each of the words was presented for 2000 ms. A blank time of 500 ms between each presentation was provided to allow the participant to reset prior to the next word.

In the experimental phase, participants were presented with 4 blocks of 19 words (The unstudied critical lure, 6 studied words related to the lure, 6 related unstudied words and 6 unrelated studied words taken from another category) in which they were required to identify whether the word was an “old” (seen in the study phase) word or “new” (not seen in the study

phase). They were then required to select the confidence in their decision with either "know" (confident they saw the word) or "remember" (think they saw the word were not entirely sure). Once 20000 ms had been reached, a timeout would occur and the next word in the block would be presented.

Experimental hardware. Each of the tasks was visually presented on a 15 inch Toshiba Satellite L540 laptop. The laptop had an Intel Core i5 2410M 2.3 GHz Processor running Windows 7 with 4GB of ram. The screen resolution was 32 bit and set at 1366 x 768 pixels.

Procedure

A potential issue that can arise in memory testing is that performance can be decremented when people are in unfamiliar locations (Russo et al., 1999). Therefore, middle and older adult participants were tested in situ (home or office locations) in order to obtain the most accurate performance. Although younger participants were tested at university, this is a familiar environment and therefore performance is unlikely to be decremented. For older people, a university environment could be daunting and therefore some of the differences in test performance might just be a function of the site of testing. The second argument is that older people may be less mobile and subsequently less inclined to travel than younger participants. Prior to administration, the tasks were counterbalanced to reduce the potential of order effects. Participants were verbally instructed to read the instructions on the laptop screen and indicate that they understood prior to the commencement of each task.

Non-verbal gist. Prior to the learning phase, the following instructions were presented on the laptop screen:

'The purpose of this task is to see how quickly you can find a particular object that you studied earlier from a grid of other objects. After you see the single object, you will see a blank screen and then you will be presented with a grid of objects. Press the numbers 1 to 4

on the keypad corresponding to the object you saw in the study phase. To make sure you are fresh when you do the object recognition test we will have you do a different task between the learning phase and the testing phase.'

Prior to the number search task, the following instructions were presented:

'*A table of numbers will be presented on the screen. Your task is to COUNT the number of 7s in the block as fast and as accurately as possible. Once you have scanned through the table enter your answer in the box provided.'*

Prior to the experimental phase of the non-verbal gist task, the following instructions were presented on the laptop screen:

'For this task you will be shown four items on the screen. You need to decide which of the four items was the one that you saw in the initial learning phase. Press the appropriate key under the item to indicate your response. Your responses are timed but don't rush.'

Verbal gist. Prior to each of the initial learning phases, the following instructions were presented:

'In this study we will be asking you to remember sets of related words. We are looking at how you process language and your memory for related words. In this study you will be first presented with a list of words for you to remember. We will call these "old words." Later you will be presented with a second list that contains the "old words" and some related new words that you did not study. You will be asked to decide which words you have seen before and how confident you are that you have seen the word. So it's very important that you try to remember all the words you are presented with in the study phase. The process will be repeated 4 times to make sure we get an accurate picture of your memory for these words. In each trial you will have an opportunity to study a list of 12 words a short delay and then your memory for these words will be tested. You are about to be presented with a list of words to study. Try to remember each word in the list. Each word will be presented for 2

seconds and then replaced with a new word. Try to remember as many words as you can. After you have studied the words there will be a brief pause and then you will be presented with a word recognition task. If you understand the task press any key to continue.

Prior to the initial experimental phase, the following instructions were presented on the laptop screen:

'In this part of the task you need to tell us if the words on the screen were in the list you studied or not. If you believe that the word on the screen is one of the old words that you studied in any of the learning phases press the "Z" key on the left of the keyboard. If you believe that it's a new word (one you have not seen in any of the learning phases) press the "/" on the right side of the keyboard to indicate it is a new word.
You will then be asked about the confidence you have in your decision by asking if you know (are you confident you can definitely recall the word) or remember (think you saw the word in the studied list but you are not entirely sure). Press the "Z" key on the left of the keyboard if you "know" you saw the word previously or "know" you haven't seen the word before (in any of the learning phases). Press the "/" on the right of the keyboard if you think you "remember" seeing the word or do not "remember" seeing the word but are not entirely sure (in any of the learning phases). Your responses will be timed but don't rush and make any typing errors. Press any key to continue.'

Prior to the second, third and fourth experimental phases the following instructions were presented on the laptop screen:

'Press space when you are ready to continue. You will see another set of items to study, and then asked if they are old or new items.'

Design

Non-verbal gist. A between subjects design was used. The independent variable was *Age* (Young (18-49), Middle Old (50-64), and Older Adults (65 and above)). The dependent

variables were *Recognition to Identify Pictorial Stimuli* (Target, Semantically Related, Functionally Related, Unrelated) and *Latency to Identify Pictorial Stimuli* (Target, Semantically Related, Functionally Related, Unrelated)

Verbal gist. A between subjects design was used. The independent variable was *Age* (Young (18-49), Middle Old (50-64), and Older Adults (65 and above)). The dependent variable was *Proportion of Error* (Target, Critical Lures, Semantically Related, and Unrelated).

Results

Preliminary Analysis

All data was screened and analysed using IBM SPSS Statistics 21.

Non-verbal gist. Prior to analysis, the assumptions of MANOVA were tested. The assumption of sample size was met. Violations of normality were identified for all DVs using Kolmogorov-Smirnov ($p > .05$). However, MANOVA is robust to moderate violations of normality with larger sample sizes (Tabachnick & Fidell, 2007). The data were linear. Three multivariate outliers were removed from the analysis. High correlations ($r > .7$) were identified between *Target* and *Semantically Related Items* as well as *Target* and *Functional Items*. One approach could be to remove redundant measures from the analysis. As this analysis is exploratory and we were interested in overall performance, all measures were analysed and results were interpreted with caution. Box's M was violated for *Latency to Identify Pictorial Stimuli* ($F(20, 13597) = 4.124$, $M = 90.95$, $p < .001$). As Box's M was violated, a more conservative *Pillai's criterion* was used to interpret multivariate significance unless otherwise indicated. No missing data was identified.

Verbal gist. Prior to analysis, the assumptions of MANOVA were tested. The assumption of sample size was met. Violations of normality were identified for all DVs using

Kolmogorov-Smirnov ($p < .05$). However, MANOVA is robust to moderate violations in normality with larger sample sizes (Tabachnick & Fidell, 2007). The data were linear. One multivariate outlier was removed from the analysis. The DVs of *Critical Lure* and *Semantically Related* and *Critical Lure* and *Unrelated Items* were approaching singular ($r > .9$). As we were more interested in performance on *Semantically Related Items,* the redundant variables of *Critical Lure* and *Unrelated Items* were removed from the analysis. There was still high correlation ($r > .7$) between *Target* and *Semantically Related Items.* As this analysis is exploratory and we were interested in overall performance, both measures were analysed and results interpreted with caution. Box's *M* was violated ($F(6, 85407) = 5.81$, $M = 35.95$, $p < .001$). As Box's *M* was violated, a more conservative *Pillai's criterion* was used to interpret multivariate significance (Tabachnick & Fidell, 2007). No missing data was identified.

Main Analysis

As there was an unbalanced design, *gender* and *education* were not included in the final analysis.

Non-verbal gist. A ONEWAY between groups MANOVA (Multivariate Analysis of Variance) was conducted to assess the effect of *Age* (Young Old (18-49), Middle Old (50-64), and Older Adults (65+)) on *Recognition to Identify Pictorial Stimuli* (Target, Semantically Related, Functionally Related, Unrelated). α was set at .05 apriori. There was a significant effect of *Age* on *Recognition to Identify Pictorial Stimuli* (F_{wilks} (8, 120) = 2.06, $p = .045$, partial $\eta^2 = .12$, power = .81). As the overall test of the weighted linear composite was significant, each of the dependent variables was then considered separately.

Analysis of the dependent variables separately showed that there was a significant effect of *Age* on *Recognition of Target Pictorial Stimuli*, with older adults recognising fewer target stimuli than young and middle old adults ($F(2, 63) = 7.30$, $p = .001$, partial $\eta^2 = .19$, power = .93). To investigate group differences between *Age,* a series of post hoc analyses

were conducted using *Tukey's HSD* with $\alpha = .05$. Tukey's test was used, as it is a moderately conservative post hoc to control for familywise error rate over entire sets of pairwise comparisons (Keppel & Wickens, 2004). There was a significant difference on recognition of the target picture between young and older adults, with older adults recognising fewer target stimuli than young adults (Refer to Table 29 below). There was also a significant difference between middle old and older adults, with older adults recognising fewer target stimuli than the middle old adults (Refer to Table 29 below). However, there was no significant difference between young and middle old adults (Refer to Table 29 below).

Table 29

Recognition of Pictorial Stimuli by Age Group: Mean and Standard Deviations for Young Old, Middle Old, and Older Adults

	Age Group		
Types of Recognition	Young Old *M* *(sd)*	Middle Old *M* *(sd)*	Older Adults *M* *(sd)*
Target	.94[a] *(.10)*	*.96[b]* *(.04)*	.87 *(.09)*
Semantically Related	.04[a] *(.06)*	.02[b] *(.03)*	.09 *(.07)*
Functionally Related	.02 (.04)	.01 (.02)	.03 (.04)
Unrelated	.00 (.01)	.00 (.01)	.01 (.02)

NB: a – Difference between young and older adults, b – Difference between young and middle old adults

There was also a significant effect of *Age* on *Recognition of Semantically Related Pictorial Stimuli*, with older adults recognising more semantically related stimuli than young and middle old adults ($F(2, 63) = 7.72$, $p = .001$, partial $\eta^2 = .20$, power = .94). To investigate group differences between *Age*, a series of post hoc analyses were conducted using *Tukey's HSD* with $\alpha = .05$. There was a significant difference between young and older adults, with older adults recognising more semantically related stimuli than young adults (Refer to Table 29 above). There was also a significant difference between middle and older adults, with older adults recognising more semantically related stimuli than middle old adults (Refer to Table 29 above). However, there was no significant difference between young and middle old adults.

However, there was no significant effect of *Age* on *Recognition of Functionally Related Pictorial Stimuli* ($F(2, 63) = 1.93$, $p = .15$, partial $\eta^2 = .06$, power = .39) (Refer to Table 29 above). There was also no significant effect of *Age* on *Recognition of Unrelated Pictorial Stimuli* ($F(2, 63) = .84$, $p = .44$, partial $\eta^2 = .03$, power = .19) (Refer to Table 29 above).

As can be seen in Table 28 above, older adults recognise significantly fewer target stimuli than the young and middle old adults. In addition, they recognise significantly more stimuli that are semantically related to the target. This is consistent with the idea that older adults are remembering the general characteristics of the stimuli, rather than the specific detail.

Latency. A ONEWAY between groups MANOVA (Multivariate Analysis of Variance) was conducted to assess the effect of *Age* (Young Old (18-49), Middle Old (50-64), and Older Adults (65+)) on *Latency to Identify Pictorial Stimuli* (Target, Semantically Related, Functionally Related, Unrelated). α was set at .05 apriori. There was a significant effect of *Age* on *Latency* ($F_{pillai's}(8, 122) = 4.00$, $p < .001$, partial $\eta^2 = .20$, power = .99). As the overall test of the weighted linear composite was significant, each of the dependent variables was then considered separately.

Analysis of the dependent variables separately, showed that there was a significant effect of *Age* on *Latency* to *Recognise Target Pictorial Stimuli*, with older adults taking longer to recognise target pictorial stimuli than young and middle old adults ($F(2, 63) = 10.09$, $p < .001$, partial $\eta^2 = .24$, power = .98). To investigate group differences between *Age*, a series of post hoc analyses were conducted using *Tukey's HSD* with $\alpha = .05$. There was a significant difference between young and older adults, with older adults taking longer to recognise target pictorial stimuli than young adults (Refer to Table 30 below). In addition, there was a significant difference between younger and middle old adults, with middle old

adults taking longer to recognise target pictorial stimuli than young adults (Refer to Table 30 below). However, there was no significant difference between middle and older adults (Refer to Table 30 below).

Table 30

Latency (ms) to Recognise Pictorial Stimuli by Age Group: Mean and Standard Deviations for Young Old, Middle Old, and Older Adults

	Age Group		
Types of Recognition	Young Old *M* *(sd)*	Middle Old *M* *(sd)*	Older Adults *M* *(sd)*
Target	1889[ab] *(457)*	2397 *(644)*	2769 *(855)*
Semantically Related	145[a] *(222)*	100[c] *(188)*	440 *(400)*
Functionally Related	61 (104)	79 (187)	102 (143)
Unrelated	33 (150)	12 (36)	36 (84)

NB: a – Difference between young and older adults, b – Difference between young and middle old adults, c – Difference between middle and older adults

There was also a significant effect of *Age* on *Latency to Recognise Semantically Related Pictorial Stimuli,* with older adults taking longer to recognise semantically related pictorial stimuli than young and middle old adults ($F(2, 63) = 9.00$, $p < .001$, partial $\eta^2 = .22$, power = .97). To investigate group differences between *Age,* a series of post hoc analyses were conducted using *Tukey's HSD* with $\alpha = .05$. There was a significant difference between young and older adults, with older adults taking longer to recognise semantically related pictorial stimuli than young adults (Refer to Table 30 above). In addition, there was a

significant difference between middle and older adults, with older adults taking longer to recognise semantically related pictorial stimuli than middle old adults (Refer to Table 30 above). However, there was no significant difference between young and middle old adults. (Refer to Table 30 above).

However, there was no significant effect of *Age on Latency to Recognise Functionally Related Pictorial Stimuli* ($F(2, 63) = .46$, $p = .633$, partial $\eta^2 = .01$, power = .12) (Refer to Table 30 above). There also was no significant effect of Age on *Latency to Recognise Unrelated Pictorial Stimuli (*$F(2, 63) = .34$, $p = .711$, partial $\eta^2 = .01$, power = .10) (Refer to Table 30 above).

Verbal gist. A ONEWAY between groups MANOVA (Multivariate Analysis of Variance was conducted to assess the effect of *Age* (Young Old (18-49), Middle Old (50-64) and Older Adults (65+)) on *Proportion of Error* (Target, Critical Lures, Related and Unrelated). α was set at .05 apriori. There was a significant effect of *Age* on *Proportion of Error* ($F_{pillai's}$ (4, 126) = 6.15, $p < .001$, partial $\eta^2 = .16$, power = .99). As the overall test of the weighted linear composite was significant, each of the dependent variables was then considered separately.

Analysis of the dependent variables separately showed that there was a significant effect of *Age* on *Proportion of Error for Target Recognition*, with younger adults having a higher proportion of error in recognising target stimuli than middle and older adults ($F(2, 63) = 10.53$, $p < .001$, partial $\eta^2 = .25$, power = .99). To investigate group differences between *Age,* a series of post hoc analyses were conducted using *Tukey's HSD* with $\alpha = .05$. Tukey's test was used, as it is a moderately conservative post hoc to control for familywise error rate over entire sets of pairwise comparisons (Keppel & Wickens, 2004). An unexpected finding was although there was a significant difference between the young and old adults; the young adults had a higher proportion of error in recognising target stimuli than older adults (Refer to

Table 31 below). There was a significant difference between the young and middle old adults, but again young adults had a higher proportion of error in recognising target stimuli than middle old adults (Refer to Table 31 below). However, there was no significant difference between middle and older adults (Refer to Table 31 below).

Table 31

Proportion of Error for Recognition of Verbal Stimuli by Age Group: Mean and Standard Deviations for Young Old, Middle Old, and Older Adults

	Age Group		
Types of Recognition	Young Old *M* *(sd)*	Middle Old *M* *(sd)*	Older Adults *M* *(sd)*
Target	.47[ab] *(.21)*	.19 *(.17)*	.27 *(.28)*
Semantically Related	.60[ab] (.15)	.89 (.19)	.86 (.23)

NB: a – Difference between young and older adults, b – Difference between young and middle old adults

There was a significant effect of *Age on Proportion of Error for Semantically Related Item Recognition*, with middle and older adults having a higher proportion of error in recognising semantically related stimuli than young adults ($F(2, 63) = 14.96$, $p < .001$, partial $\eta^2 = .32$, power approaching 1). To investigate group differences between *Age*, a series of post hoc analyses were conducted using *Tukey's HSD* with $\alpha = .05$. There was a significant difference between younger and older adults, with older adults having a higher proportion of error in recognising semantically related stimuli than young adults (Refer to Table 31 above). There was also a significant difference between younger and middle old adults, with middle old adults having a higher proportion of error in recognising semantically related stimuli than

young adults (Refer to Table 31 above). However, there was no significant difference between the middle and older adults (Refer to Table 31 above).

Again, it was found that older adults recognised stimuli that were semantically related to the target. It was also found that middle old adults recognised stimuli that were semantically related. This again suggests older adults are making gist errors. An intriguing finding was that younger adults made significantly more errors in recognition of the target stimuli than both the young and middle old adults.

Discussion

One of the aims of the research was to assess whether older people are more likely to make gist errors than the younger cohort. If older adults are more likely to remember the general idea or gist, this may provide evidence that there is some level of cognitive decline. From the literature (e.g., Hudon et al., 2006), there was some indication that older adults are better at remembering the general idea over specific detail. Therefore, it was predicted that older adults were more likely to make gist errors than younger adults.

As predicted, older adults were less able to accurately recognise the target on the pictorial task than the younger and middle older adults. This might suggest that older adults were unable to encode a specific episodic trace of the target picture. For example, a target of a specific umbrella is encoded as distinct from a generic representation of an umbrella, or something you use to keep dry (which may elicit a macintosh). It is thought that a specific episodic or item specific trace is more likely to be encoded when the trace is distinctive and a new association is stored over a new set of units. However, the pictures presented in the task were of common everyday items e.g., lamps, dogs and cats which are unlikely to be distinctive to the older adults and therefore a general representation was most likely stored.

In addition, it was found that older adults recognised more of the semantically related items (e.g., recognising the red shirt when the black shirt was the target) than the younger and middle old adults. The finding that older adults were less accurate in recognising the item specific target and more likely to identify the item that is semantically similar supports the argument that older adults are storing generally rather than as a unique trace.

A puzzling finding was that younger adults were less accurate in recognising the target and made more semantically related errors than the middle adults, albeit not significantly. This could suggest that the younger participants had some level of difficulty during the initial study phase and therefore only encoded a general representation of the item, rather than the specific details. This finding provides partial support for Guerin et al.'s (2012) research that found younger adults still made gist errors in the presence of the target.

However, it was found that there was no significant difference between the three cohorts on functionally related and unrelated related items. This suggests that the older adults did not make gross semantic confusions, which might suggest some preservation of specificity of encoding. However, it is possible that differences on functionally and unrelated items may have been detected in more cognitively impaired individuals.

A potential limitation of the task was the differentiation between semantically, functional and unrelated item in that some of the unrelated items could be classified as related and thus still had some relatedness to the target item. For example, one could argue that some of the unrelated items could still be classified as being somewhat related to the task (e.g., a hockey stick is still related to a ball because it is used for sporting purposes). In addition, some of the functionally related may also have been classified as semantically related (e.g., for the glasses category a pair of sunglasses was used as a functionally related item). Since the main focus was to assess whether older adults are more likely to make gist errors, future research may consider eliminating the functionally related and unrelated category and

implementing more semantically related items. However, despite the lack of a distinct differentiation between items, it was still found that older adults consistently selected the item that would be considered most semantically related to the target.

It was found that older adults were significantly slower in the recognition of both target and semantically related pictorial stimuli than young and middle old adults. It was also identified that middle old adults were significantly slower than the young adults in recognising target pictorial stimuli. As there was some evidence of a decline in accuracy, this suggests generalised slowing and as discussed in the previous chapter, may be as a result of an increase in amyloid β build-up. This increase in amyloid β build-up may then result in disturbances of neural network activity or neuronal death (Cramer et al., 2012; Palop & Mucke, 2010). There is also some evidence that this may begin to occur in middle adulthood.

In addition, it was found that functionally and unrelated latencies were not significant. However, this is likely to be as a result of older adults identifying more semantically and target items over functionally related and unrelated items. As mentioned previously, it is likely that older adults still retain some level of detail of stimuli and therefore are unlikely to make these types of errors. Again, it is possible that cognitively impaired individuals would have identified more functional and unrelated items.

A puzzling finding, however, was that younger adults made significantly more errors in recognition of target on the verbal task than the middle and older adults. One would expect that younger adults should be able to form an item specific representation, however, this does not seem to be the case. This could indicate a damaged cohort of younger adults. Alternatively, it could indicate a task demand characteristic in that the younger adults found the task too easy or trivial.

As predicted, it was found that both middle and older adults made significantly more semantically related errors. The fact that these cohorts identified more semantically related

items suggest that they are still likely to recognise an item that is semantically similar to the target. Moreover, the finding that middle old adults were more likely to select semantically related items suggests that storing generally may begin to occur in middle adulthood.

A potential limitation of the task was the lack of practice trials given prior to commencing the test phase. Future research could consider incorporating practice trials prior to the commencement of the test phases to ensure that participants have an adequate understanding of the task. Another potential issue was that participants were only provided one trial of each set of words. Budson et al. (2000) found that recognition increased after repeated presentations of the trials, which may suggest that several repetitions of the task could increase memory performance. However, it could be argued that the repeating presentations of stimuli could cause induce potential artifacts and increase the likelihood for intrusion errors.

A further aim was to assess whether age related decline is modular or generalised. On the non-verbal gist task, there was evidence of decline for recognition of target and increased tendency to make gist errors. This provides some evidence of generalised decline in the older adults. Although older adults also made gist errors on the verbal gist task, they were also able to recognise target stimuli. Although it is not entirely clear, there is some indication of dissociation between verbal and non-verbal representations. This provides support for modular decline with increasing age and suggests that decline may occur differentially throughout the brain.

Overall Conclusions

Overall, there is evidence to suggest that older adults are storing generally, as they had a propensity to make gist errors on both verbal and non-verbal gist tasks. Although older adults had higher recognition of the target on the verbal gist task than the younger adults, this could be indicative of performance decrement in the younger adults rather than lack of

decline in the older sample. There was also some indication that remembering the general detail of stimuli may occur earlier as middle old adults also had a tendency to make gist errors on the verbal gist task. As the verbal gist task was capable of detecting differences in the middle old adults, this might suggest that it has utility as a screening measure in the detection of incipient cognitive decline.

To further investigate the effects of age on memory, the next study will investigate implicit and explicit memory processes.

Chapter 7

Study 5: Assessing differences in implicit and explicit memory between younger, middle old and older adults

To further explore the effect of age on memory, implicit and explicit memory processes were investigated. In the second and third studies it was identified that older adults have lower span. Digit span is considered a measure of explicit memory, as participants are consciously instructed to remember the digits followed by a specific cue that prompts retrieval. Since it was identified that older adults decline on span in two of the studies, it was predicted that decline would also be evident in the current study. However, previous research (e.g., Light et al., 1986) has identified that implicit memory is invariant with age.

Light, Singh, and Capps (1986) investigated the effects of aging on implicit and explicit memory using participants who were assessed in two experimental sessions. In the first session, 20 x 2 blocks of words were presented. The test words for each session contained 20 old and 20 new words that were further divided into 10 old and 10 new for conditions A and B. Each participant received the testing order of Recognition A, Stem Completion B, Stem Completion A and Recognition B so half of the targets were tested first on recognition and half on stem completion. This allowed the authors to assess the effects of studying the targets and whether priming took place. For the stem completion part of the task, participants were provided fragmented low frequency words containing 7 or 8 letters. The second session was conducted 7 days later to assess the remaining targets and participants were provided the same testing condition as the initial session. Light et al. (1986) found that although younger adults scored significantly higher on the recognition task, older adults were not significantly different to the younger cohort on the stem completion task.

Spaan and Raaijmakers (2011) also investigated the effects of aging on implicit and explicit memory. A sample of 170 participants that were divided into four specific age cohorts: 55-64, 65-74, 75-84 and 85 and above. Participants were administered a priming task followed by a word stem completion task. In addition, they were administered a neuropsychological battery consisting of explicit memory measures (e.g., cued recall). Similar to Light et al.'s (1986) study, Spaan and Raajmakers (2011) found that priming was largely invariant with age. Again, older adults were found to decline on the explicit memory measures. A surprising aspect of Spaan and Raajmakers's (2011) research was the lack of a younger aged cohort for comparison purposes and it is possible that the middle old may have had decline in performance relative to younger participants. The current study included middle old adult participants (50-64) to enable the potential trends to be identified from young old, through to middle old to older adults. From the research of Light et al. (1986) and Spaan and Raaijmakers (2011), there is some indication that implicit memory remains invariant with age. However, there is also evidence that memory for explicit material may be more vulnerable to age related decline.

An earlier study conducted by Schugens, Daum, Spindler, and Birbaumer (1997) also investigated the effects of aging on implicit and explicit memory. Participants were divided into five age cohorts ranging from 20 to 72 years: 20-29, 30-39, 40-49, 50-59, 60-72 years. Implicit memory was measured using a stem completion task and perceptual skill acquisition task. In the stem completion task, participants were initially shown 16 targets that were rated according to liking followed by a 3-minute distractor task. Preceding the distractor task, participants were provided a cued recall task in that they were shown 16 targets from the study phase and explicitly instructed to complete the stems. They were then presented a forced choice recognition test in which each target was presented with semantically and unrelated distractors. In the perceptual skill acquisition task, participants were initially

required to learn to present words that had been mirror reversed. In the training phase, participants were presented triads of unrelated low-frequency nouns that were mirror reversed. Participants were provided two training sessions that comprised of 20 triads. In the second training session, participants were provided 10 triads from the first session and an additional 10 trials presented randomly. The improvement across sessions for items that had been repeated would be considered a priming effect (Schugens et al., 1997). In addition, the improvement for recognition of unique items would be considered a measure of skill learning. Prior to the two training sessions, participants were provided a recognition test of 40 words; 20 target words from the prior test and 20 distractor words and were required to indicate which words that they had seem previously. Participants were also administered explicit memory measures in the form of verbal and visual tasks. In the verbal explicit memory task, participants were assessed using an immediate and recall of a prose passage. Participants were also measured on the number of items recognised in the mirror reading and cued recall, and recognition of targets on the stem completion task. Visual memory was assessed using a recall task requiring participants to copy a complex geometric figure and recognition assessed using a face recognition task.

Schugens et al. (1997) found that performance on both verbal and visual explicit recall tasks showed a steady decrease starting from the age of 20. However, Schugens (1997) found no differences between the age cohorts on the explicit memory recognition tasks. The authors partially attribute this finding to ceiling effects on the word and face recognition tests. On the implicit memory measures, it was found that there was no effect of age on perceptual skill acquisition. In contrast to Light et al. (1986) and Spaan and Raaijmakers (2011), significant age related decline was found on the stem completion task. However, Schugens et al. (1997) suggest this finding might be attributed to contamination of explicit memory. This was supported through a factor analysis, which identified that priming loaded onto a factor

comprising of explicit memory. On the basis of this finding, Schugens et al. (1997) suggested that visually presenting word stems might have acted as a retrieval cue and induced explicit memory processes. In addition, they suggested that the lack of time delay between tasks and use of instructions might also have induced the use of explicit strategies.

Perri, Serra, Carlesimo, and Caltagirone (2007) assessed implicit and explicit memory in individuals with amnestic mild cognitive impairment, individuals with Alzheimer's disease, and healthy older adult controls. As part of the study, implicit memory was assessed using a repetition-priming task (non-verbal) and stem completion task (verbal). Participants were also provided a visual-perception repetition-priming task in which they were required to identify a set of 14 drawings with 7 levels of fragmentation. In the following session, they were provided the same testing procedure with, however, a new set of 7 drawings presented. Priming was considered the amount of improvement in performance from the new set of drawings to identification of old set of drawings in the second session. In addition, explicit memory measures were used including word list recall, word list recognition, prose recall and a reproduction task.

Perri et al. (2007) found a robust priming effect for all cohorts on the stem completion test, however, Alzheimer's disease participants had significantly reduced priming compared to the mild cognitive impairment and healthy older adult controls on the visual perception task. Moreover, it was found that both amnestic mild cognitive impairment and Alzheimer's disease participants had poorer performance on measures of explicit memory when compared to healthy controls. These results suggest that participants with Alzheimer's disease demonstrate intact priming on verbal stimuli but show evidence of decline for visual material (Perri et al., 2007). However, the authors suggested that explicit memory processes contaminated performance on the fragmented picture identification task more than the stem completion test. Similar to the criticism of the study by Spaan and Raaijmakers (2011), a

limitation of the study was the lack of a suitable aged cohort, resulting in an inability to infer whether older adults decline relative to a younger aged cohort.

Shum, O'Gorman, and Eadie (1999) assessed non-verbal implicit memory using the Shum Visual Learning Test (SVLT; Shum et al., 1999). On this task, participants were provided a form of instruction that did not explicitly instruct them to learn the characters. For the first five learning trials, participants were presented the same target stimuli and distractor characters. It is thought that presenting the same characters on each trial creates proactive interference. Therefore on Trial 6, a different set of target and distractors were presented. The presentation of a different set of stimuli is designed to release proactive interference and facilitate memory performance. For Trials 7 and 8, participants were presented the original set of stimuli without the initial learning phase. Trial 7 is designed to measure retention after interference. A 20-minute interval is also administered between the two trials. Therefore, Trial 8 is designed to assess delayed retention.

Participants were divided into seven age cohorts aged from 17-70+: 17-19, 20-29, 30-30, 40-49, 50-59, 60-69 and 70 and above. Shum et al. (1999) found that the individuals in the 60-69 cohorts recognised significantly fewer characters than participants in the two younger cohorts over the first five trials. It was found that the individuals in the 70 and over group recognised significantly fewer characters than all younger cohorts except for the individuals' aged 50-69. In addition, individuals in the 70 and above age group recognised significantly fewer characters than the first 4 aged cohorts on Trial 7 and the 17-19 cohort on Trial 8. This is contrary to Light et al. (1986), Schugens et al. (1997) and Spaan and Raaijmakers (2011) who found little evidence of implicit memory decline with age.

Aims of Research

From the research (e.g., Light et al., 1986; Spaan & Raaijmakers, 2011), there is evidence to suggest that memory for implicit material may remain preserved. Therefore, it

was predicted that no age differences would be identified on the implicit memory measures. There is some indication from the second and third studies reported earlier to suggest older adults decline in span. Therefore, it was anticipated that older adults would have lower recall than the younger adults on the span task. This would suggest decline in explicit memory.

A further aim was to assess whether age related cognitive decline is modular or generalised. If decline in explicit memory is observed but implicit memory remains intact, this would provide evidence for a dissociation of memory processing and support a theory that age related changes occur in distinctive parts of the brain that decline at different rates. However, if decline is observed in both implicit and explicit memory, this would support the idea of generalised decline and that age related changes occur across the entire brain. If decline is observed in nonverbal implicit memory but not verbal implicit memory, this would be indicative of dissociation between verbal and nonverbal implicit memory processes, providing further support for a modular decline.

Method

Participants

The participants used were from the same cohort as in the previous study. A purposive sampling technique was used. Although purposive sampling is not as effective as stratified random sampling and is not be representative of the population, this technique is useful in gathering participants that share particular characteristics (Babbie, 2007). In this research, the particular characteristic of interest was independent living healthy older adults. The participants that comprised the young old sample were first year psychology students from a university that received course credit for participation in the research. The other participants were recruited from the local community. Screening of the data lead to the final sample of 66 comprising of 49 females (74.2%) and 17 males (25.8%). The age of the entire

sample ranged from 18 to 86 years (M = 50.27, SD = 21.06). For highest education obtained, 40 (60.6%) participants nominated high school, 17 (25.8%) university, 5 (7.6%) nominated T.A.F.E/college and 4 nominated primary school (6.1%). From the participants, 36 (30.45%) were currently taking medication for illnesses e.g., high blood pressure, high cholesterol, diabetes, vascular problems. The other 30 participants (45.5%) were not currently taking medication. Chi-square analysis was also conducted to assess whether there was a difference in medical status by gender. However, this was not significant (χ^2 (1, n = 66) = 3.42, p = .064). Refer to Table 32 below.

Table 32

Cross-Tabulation of Medical Status x Gender

Gender	Medical Status	
	Taking medication	Were not taking medication
Males	11 (36.7%)	6 (16.7%)
Females	19 (28.8%)	30 (45.5%)

The participants were divided into three groups depending on age. The younger adults group (18-49) consisted of 24 participants with ages ranging from 18 to 46 (M = 25.04, SD = 8.2) with 22 (91.7%) females and 2 (8.3%) males. From the sample, 18 (75.0%) participants nominated high school, 3 (12.5%) university, and 3 (12.5%) nominated primary school as the highest level education obtained. One (4.2%) of the participants was taking medication for illnesses e.g., high blood pressure, high cholesterol, diabetes, depression, vascular problems. Twenty-three (95.8%) participants were not taking medication.

The middle adults group (50 to 64) consisted of 21 participants with ages ranging from 50 to 64 (M = 57.38, SD = 5.00) with 15 (71.4%) females and 6 (28.6%) males. From

the sample, 9 participants (42.9%) nominated university, 8 (38.1%) high school, and 4 (12.5%) T.A.F.E/college as highest level of education obtained. Nine (42.9%) of the participants were taking medication for illnesses e.g., high blood pressure, high cholesterol, diabetes, depression, vascular problems. Twelve (42.9%) participants were not taking medication.

The older adults group (65 and above) consisted of 21 participants with ages ranging from 65 to 86 (M = 72.00, SD = 5.24) with 12 (57.1%) females and 9 (42.9%) males. From the sample, 14 (66.7%) nominated high school, 5 (23.8%) university, 1 (4.8%) nominated T.A.F.E/College and 1 (4.8%) nominated primary school as highest level of education obtained. Twenty (95.2%) of the participants were taking medication for illnesses e.g., high blood pressure, high cholesterol, diabetes, depression, vascular problems. One (4.2%) participant was not taking medication.

Chi-square analysis was also conducted to assess whether there was a difference in medical status by age and was found to be significant ($\chi^2(2, n = 66) = 37.55, p < .001$). Refer to Table 33 below.

Table 33

Cross-Tabulation of Medical Status x Gender

	Medical Status	
Age	Taking medication	Were not taking medication
Young Old	1 (1.5%)	23 (34.8%)
Middle Old	9 (13.6%)	12 (18.2%)
Older Adults	20 (30.3%)	1 (1.5%)

Instruments

Non-verbal implicit memory. To assess non-verbal implicit memory, the Shum Visual Learning Test (SVLT; Shum et al., 1999) was used. The stimuli for each of the six learning phases consisted of 10 Chinese characters. The stimuli for the experimental component of the task were 20 Chinese characters. Ten of the characters presented were from the initial learning phase. The other 10 Chinese characters were also previously shown in the learning phase but with a stroke added or removed to act as distractors.

For each of the first five learning trials, participants were instructed to count the strokes for each character. The instructions were intended to distract them from the intended nature of the task. On each of the trials, participants were presented the same Chinese characters. Each of the characters was presented for 3000 ms to ensure implicit learning had occurred. A blank time of 500 ms was presented between each Chinese character to allow the participant to reset prior to the presentation of the next word.

For the first five experimental phases, participants were presented 20 Chinese characters that were counterbalanced in order. Ten of the characters presented were from the

initial learning phase. The other 10 characters presented were also from the learning phase but had an extra stroke added or removed from them, designed to act as distractors. Participants were required to indicate by typing the appropriate key on the keyboard as to whether they had seen the character previously or not seen the character before. Each of the characters was presented for 15000 ms before the task would time out and the next character presented. It is thought that presenting the same characters on each trial creates proactive interference.

On the Trial 6, participants were given the same instructions as the previous trials on learning and test phase but were presented a different set of characters. This manipulation was designed to release the individual from proactive interference[16] and facilitate memory performance.

Participants were not provided the initial learning trial on the seventh and eighth trials. On both trials, participants were tested on the same set of characters from the initial five trials. Trial 7 was designed to measure retention after interference. Following the Trial 7, a 20-minute interval was provided and therefore Trial 8 was designed to assess retention after delay. Refer to Figure 16 for stimuli from the task.

Figure 16. Stimuli from Non-Verbal Implicit Memory Task

Verbal implicit memory. To assess verbal implicit memory, a stem completion task was used. The stimuli for the vocabulary-learning phase consisted of 40 nouns each consisting of 5 letters. Twenty of the words were high familiarity words and 20 were low

[16] Old material impedes learning of new information

familiarity words. The words for the stem completion task were taken from a subsample of 6000 words derived from a 100 thousand word list based on the Corpus of Contemporary American English, the British Natural Corpus (BNC), Corpus of American Soap Operas (SOAP) and Corpus of Historical American English (COHA). The high frequency words were selected with a dispersion of over 0.90 and total frequency of over 1050. The low frequency words were selected with a diversion of under 0.90 and total frequency under 250 (Davies, 2011). Each of the words was matched for target word and syllable length. Refer to Appendix D for the list of stimuli used in the stem completion task.

In the learning phase, participants were presented 40 words each consisting of 5 letters in length. During the learning phase, participants were required to form a general impression of how familiar the word was to them. As this was an implicit task where learning is intended to be unintentional, participants were provided with instructions designed to distract them from the intended nature of the task. Each of the words was presented for 2000 ms to ensure implicit learning had occurred. A 500 ms blank time was presented to allow the participant to reset prior to the presentation of the next word.

A number search task was presented prior to the experimental phase. In the number search task, participants were presented blocks of numbers and were required to search for the number 7. This was designed to provide a longer time period between learning and experimental phases and make the task more difficult.

In the experimental phase, participants were presented 50 trials. On each trial, a 3-letter stem was presented with either an “old word” presented from the learning phase, or a “new word” that had not been seen previously. Each of the stems was presented with two question marks on the end (e.g., fev??) Participants were provided with 15000 ms to respond before the task would time out and the next stem would be presented.

Explicit memory. A digit span task was used as an explicit memory measure. The stimuli for this task were sets of numerical digits. The lowest number presented was one digit and the highest that could be reached was 15 digits. It was expected that healthy individuals would recall 7 +/ 2 digits (Miller, 1994).

The task was formulated using a stair case method where once an estimate of response threshold was obtained; stimuli were never presented far from this threshold (Kantowitz et al., 2009). The first trial began with three digits presented and each ongoing presentation would subsequently increase depending on correct recall. The sequence of numbers would continue to increase if correct and drop back a digit if an incorrect sequence was recalled. The task would end either when the participant had reached maximum span performance or once 30 trials had been completed. The 30 trials ensured maximum span performance was obtained. An average of 5 trials for both accuracy and latency was taken to obtain span performance. The data was taken from trials 12-17 to reduce the potential of practice and fatigue effects which may have occurred during the start or end trials; thereby ensuring the most reliable measure of performance.

For each trial, the display time of the stimuli was 3000 ms to ensure sufficient encoding of the digits. A 2000 ms blank time was presented and then participants were provided 10000 ms to recall each trial of digits. Once 10000 ms had been reached, a timeout would occur and the next trial would be presented with one digit removed.

Experimental hardware. Each of the tasks was visually presented on a 15 inch Toshiba Satellite L540 laptop. The laptop had an Intel Core i5 2410M 2.3 GHz Processor running Windows 7 with 4GB of ram. The screen resolution was 32 bit and set at 1366 x 768 pixels.

Procedure

A potential issue that can arise in memory testing is that performance can be decremented when people are in unfamiliar locations (Russo et al., 1999). Therefore, middle and older adult participants were tested in situ (home or office locations) in order to obtain the most accurate performance. Although younger participants were tested at university, this is a familiar environment and therefore performance is unlikely to be decremented. For older people, a university environment could be daunting and therefore some of the differences in test performance might just be a function of the site of testing. The second argument is that older people may be less mobile and subsequently less inclined to travel than younger participants. Prior to administration, the tasks were counterbalanced to reduce the potential of order effects. Participants were verbally instructed to read the instructions on the laptop screen and indicate that they understood prior to the commencement of each task.

Non-verbal implicit memory. Prior to the first six learning trials, the participants were provided the following instructions aurally:

'In this phase you need to watch the characters and count the number of strokes on each character'.

Prior to the first six experimental phases, the participants were provided the following instructions aurally:

'Now I am going to see if you were paying attention. Press Y if you have seen the character before or press N if you haven't' seen it before. Make sure you respond after the character is shown and the screen has gone blank. Make sure you respond even if you are unsure'.

For the 7th and 8th trials, participants were not provided a learning phase. Prior to the experimental phases, the participants were provided the following instructions aurally:

'Now you will not have to count the strokes. You will see a series of characters. Press Y for Yes if you remember the characters from the previous trials. Press N for no if you haven't seen the character before. Remember to respond when the screen is blank and make sure you respond even if you are unsure.'

Verbal implicit memory.

Prior to the implicit learning phase, the following instructions were presented on the laptop screen:

'This is an experiment in which you will be shown some 5 letter words to read'. These words vary in familiarity and your task is to form a general impression of the overall degree of familiarity of these words. Each word will appear briefly on the screen. Please read each word silently and as you go form a general impression of how familiar the word set as a whole is for you.'

Prior to the distractor task, the following instructions were presented on the laptop screen:

'*A table of numbers will be presented on the screen. Your task is to scan the numbers as fast and as accurately as possible. You are looking for the number 7. When you see a number 7 press the enter key. You will have to scan several tables for us to obtain an average search time.'*

Prior to the stem completion task, the following instructions were presented on the laptop screen:

'For this task you will see the first letters of a word presented on a screen. Fill in the last two letters to create the FIRST WORD THAT COMES TO MIND. Your responses will be timed but don't rush and make typing errors. If you can't think a word type in xx and press enter to go to the next word.'

Explicit memory. Prior to the commencement of the task, the following instructions were presented on the laptop screen:

'In this experiment we will investigate your short-term memory. You will be presented with "sets" of digits. Each new list is called a "repetition". Your task is to remember as many of the digits as you can in the sequence. You need to remember to press the enter key at the end of each set. Please wait for the instructions to appear on the screen asking you to enter the digits before typing the sequence. If you recall the sequence in correct order the number of digits will increase by one. If you make an error the number of digits will be decreased by one. The experiment will end when you have completed 30 trials, or have exhibited stable recall'.

Design

Non-verbal implicit memory. A 3 x 8 x 2 mixed factorial design was used. The independent and between subjects variable was *Age* (Young (18-49), Middle Old (50-64), and Older Adults (65 and above)). The independent variables *Trial* (Trials 1-8) and *Target* (Hit - Correct vs. Distractor – Miss) varied within subjects. The dependent variable was *Recognition.* For each study phase on Trials 1 to 5, participants were presented 10 characters and were asked to count the strokes on each character. These instructions were designed to keep the task implicit in nature. For each test phase, the original 10 characters (hits) and 10 characters with strokes added or removed (distractors) were presented and participants were required to indicate Yes or No as to whether they had seen the character previously. The same hits and distractors were presented for the first five trials. It is thought that presenting the same characters on each trial creates proactive interference. On the Trial 6, a different set of stimuli was used, designed to provide release from proactive interference and facilitate memory performance. For Trials 7 and 8 the original stimuli were presented without the

initial learning phase. These trials were designed to measure retention after interference and delayed retention respectively.

Verbal implicit memory. A 3 x 2 mixed factorial design was used. The independent and between subjects variable was *Age* (Young (18-49), Middle Old (50-64), and Older Adults (65 and above)). The independent variable *Frequency* (High vs. Low Frequency Words) varied within subjects. The dependent variables were *Accuracy* and *Latency.*

Explicit memory. A between subjects design was used. The independent variable was *Age* (Young (18-49), Middle Old (50-64), and Older Adults (65 and above)). The dependent variables were *Mean Span* and *Mean Latency*.

Results

Preliminary analysis

All data was screened and analysed using SPSS Statistics Version 21.0.

Non-verbal implicit memory. Prior to analysis, the assumptions of MANOVA were tested. The assumption of sample size was met. Violations of normality were identified for all levels of the DV were identified using Kolmogorov-Smirnov ($p < .05$). However, MANOVA is robust to moderate violations of normality with larger sample sizes.[17] One participant was removed, as they were a Chinese speaker. An additional participant was removed as they misunderstood the task and did not respond on Trial 7. Two additional multivariate outliers were removed. The data were not multicollinear. The data were linear. The assumption of homogeneity of variance-covariance matrices was met. No missing values were identified.

Verbal implicit memory. Prior to analysis, the assumptions of MANOVA were tested. The assumption of sample size was met. Violations of normality for all levels of both DVs were identified except for *Accuracy of High Frequency Words.* However, MANOVA is

[17] Over 30 (Tabachnick & Fidell, 2007).

able to compensate for moderate violations in normality with larger sample sizes (Tabachnick & Fidell, 2007). It was identified that one younger adult, two middle old, and four older adults timed out on the task for low frequency words. Therefore, a mean imputation method was used and means of the young and middle old sample were used for the participants respectively. The four individuals in the older adult sample were imputed using 3 standard deviations above their mean as it was assumed they had significant decrement on the task. An alternative method would be to exclude the older adults with missing data. However, as they were unable to complete the low frequency words at all, this might indicate that that they are showing more signs of cognitive decline than other older adults and therefore are a cohort of interest. The data were linear. As MANOVA able to compensate for few outliers in larger sample sizes, no outliers were removed from the analysis (Tabachnick & Fidell, 2007). Sphericity was assumed. The data were not multicollinear. Box's *M* was violated for *Latency* ($F(6, 89420) = 12.24$, $M = 76.99$, $p < .001$). As Box's *M* was violated, a more conservative *Pillai's criterion* was used to interpret multivariate significance (Tabachnick & Fidell, 2007).

Digit span. Prior to running analyses, the assumptions of ANOVA were tested. The data was normal. Levene's Test indicated equal variances. No missing data was identified.

Main Analysis

As there was an unbalanced design, *gender* and *education* were not included in the final analysis.

Non-verbal implicit memory. A mixed factorial MANOVA (Multivariate Analysis of Variance) was conducted to assess the effect of *Age* (Young Old (18-49), Middle Old (50-64), and Older Adults (65+)), *Trial* (Trials 1-8) and *Target* (Hit vs. Distractor) on *Recognition*. α was set at .05 apriori. The assumption of sphericity for violated for *Trial and*

Trial x *Target conditions*. Therefore, more conservative degrees of freedom[18] were used.

There was a significant *Age* x *Trial* x *Target* interaction ($F_{pillai's}$ (14, 116) = 1.84, p = .040, partial η^2 = .18, power = .91). To assess the 3-way interaction, the data was split by *Age* and *Target.* It was identified that there was a significant effect of *Hits* over the eight trials for the *Younger Adults* ($F_{pillai's}$ (7, 161) = 5.65, p = .002, partial η^2 = .70, power = .98). There was a significant effect of *Hits* over the eight trials for *Middle Old Adults* ($F_{pillai's}$ (7, 140) = 5.78, p = .003, partial η^2 = .74, power = .97). In addition, there was a significant effect of *Hits* over the eight trials for *Older Adults* ($F_{pillai's}$ (7, 140) = 4.91, p = .006, partial η^2 = .71, power = .95). As can be seen in Table 34 below, there is some evidence of an increase in hit recognition for all cohorts over the eight trials.

[18] A Geisser-Greenhouse correction was used as it is robust and there are more than 10 participants in each cell (Tabachnick & Fidell, 2007).

Table 34

Average Number of Hits Recognised over the Eight Trials for Young Old, Middle Old, and Older Adults

	Age Group		
	Young Old *M* *(sd)*	Middle Old *M* *(sd)*	Older Adults *M* *(sd)*
Trial 1	6.54 *(1.93)*	6.52 *(1.94)*	6.29 *(1.88)*
Trial 2	7.00 *(2.02)*	8.05 *(1.72)*	7.71 *(1.23)*
Trial 3	6.71 *(2.53)*	7.71 *(1.55)*	7.38 *(1.88)*
Trial 4	8.17 *(1.79)*	7.76 *(1.92)*	7.90 *(1.34)*
Trial 5	8.08 *(2.00)*	8.19 *(1.50)*	7.81 *(1.83)*
Trial 6	6.58 *(1.77)*	5.90 *(2.51)*	6.43 *(2.52)*
Trial 7	8.88 *(1.54)*	8.81 *(1.47)*	8.52 *(1.78)*
Trial 8	9.08 *(1.35)*	9.38 *(.87)*	8.95 *(1.53)*

There was a significant effect of *Distractors* over the eight trials for the *Younger Adults* ($F_{pillai's}$ (7, 161) = 10.60, $p < .001$, partial $\eta^2 = .82$, power approaching 1). There was also a significant effect of *Distractors* over the eight trials for *Middle Old Adults* ($F_{pillai's}$ (7, 140) = 6.95, $p = .001$, partial $\eta^2 = .78$, power = .99). In addition, there was a significant effect *Distractors* over the eight trials for *Older Adults* ($F_{pillai's}$ (7, 140) = 6.51, $p = .002$, partial $\eta^2 =$

.77, power = .98). As can be seen in Table 35 below, the three cohorts also learn significantly more distractors across the eight trials.

Table 35

Average Number of Distractors Recognised over the Eight Trials for Young Old, Middle Old, and Older Adults

	Age Group		
	Young Old *M* *(sd)*	Middle Old *M* *(sd)*	Older Adults *M* *(sd)*
Trial 1	3.29 *(1.65)*	4.38 *(2.04)*	4.57 *(1.94)*
Trial 2	4.75 *(1.73)*	5.76 *(1.81)*	5.43 *(1.91)*
Trial 3	5.08 *(2.22)*	5.29 *(2.31)*	6.62 *(1.94)*
Trial 4	5.13 (*1.66)*	5.52 *(1.81)*	6.71 *(1.90)*
Trial 5	6.17 *(2.60)*	5.81 *(2.11)*	6.95 *(1.56)*
Trial 6	4.54 *(2.02)*	4.52 *(2.56)*	4.95 *(2.33)*
Trial 7	7.25 *(2.23)*	7.57 *(1.89)*	7.95 *(1.62)*
Trial 8	7.46 *(2.15)*	7.98 *(2.52)*	8.00 *(2.02)*

Proactive interference. As can be seen in Table 35 above, the three cohorts show an increase in learning of hits across the five learning trials. However, they also show an increase in the learning of distractors suggesting some evidence of proactive interference across the first five trials (Refer to Table 34 above). As can be seen in Table 34 and 35, there

is a drop in hit and distractor recognition on the release from proactive interference trial (Trial 6) and scoring returns almost to baseline responding. Following the release from proactive interference trial, there is an increase in hit and distractor recognition on Trials 7 and 8 for all cohorts.

Although there was a significant 3-way interaction, each of the 2-way interactions were also considered. There was a significant *Age* x *Target* interaction ($F(2, 63) = 3.87$, $p = .026$, partial $\eta^2 = .11$, power = .68). To assess the influence of *Age* within levels of *Target*, *Trial* was collapsed and a series of ONEWAY between groups univariate ANOVAs was conducted. α was set at .05 apriori. Rather than taking the average of the eight trials, which include the learning and release from interference phases, only Trials 7 and 8 were analysed. On Trial 7 there was no significant effect of *Age* on *Hits* $F(2, 63) = .30$, $p = .744$, partial $\eta^2 = .01$, power = .10) or *Distractors* $F(2, 63) = .72$, $p = .495$, partial $\eta^2 = .02$, power = .17). On Trial 8, there was no significant effect of *Age* on *Hit* $F(2, 63) = .62$, $p = .542$, partial $\eta^2 = .02$, power = .05) or *Distractors* ($F(2, 63) = .55$, $p = .649$, partial $\eta^2 = .01$, power = .12).

There was also a significant *Target x Trial* interaction ($F_{pillai's}$ (7, 441) = 3.47, $p = .004$, partial $\eta^2 = .29$, power = .95). To assess the differences between levels of *Target* (Hit and Distractors) for each set of *Trials*, a series of paired *t*-tests was conducted. α was set at .05 apriori.

It was identified that *Hits* were recognised more than *Distractors* on Trial 1 ($t(65) = 10.27$, $p = .000$, partial $\eta^{2\,=}$ .62) (Refer to Table 36 below). It was identified that *Hits* were recognised more than *Distractors* on Trial 2 ($t(65) = 10.10$, $p = .000$, partial $\eta^{2\,=}$ .62) (Refer to Table 35 below). It was identified that *Hits* were recognised more than *Distractors* on Trial 3 *(*$t(65) = 5.88$, $p = .000$, partial $\eta^{2\,=}$ .35) (Refer to Table 36 below). It was identified that *Hits* were recognised more than *Distractors* on Trial 4 *(*$t(65) = 8.42$, $p = .000$, partial $\eta^{2\,=}$ .52) (Refer to Table 36 below).

Table 36

Average Number of Hits and Distractors Recognised over the Eight Trials

	Targets	
	Hits	Distractors
Trials	*M* *(sd)*	*M* *(sd)*
Trial 1	6.45* *(1.89)*	4.05 *(1.93)*
Trial 2	7.56* *(1.74)*	5.29 *(1.84)*
Trial 3	7.24* *(2.01)*	5.64 *(2.22)*
Trial 4	7.95* (1.67)	5.76 (1.88)
Trial 5	8.03* (1.78)	6.30 (2.18)
Trial 6	6.32* (2.25)	4.67 (2.28)
Trial 7	8.74* (1.58)	7.58 (1.96)
Trial 8	9.14* (1.28)	7.80 (2.21)

NB: *-p<.001

It was identified that *Hits* were recognised more than *Distractors* on Trial 5 ($t(65) = 6.40$, $p = .000$, partial $\eta^{2 =} .39$) (Refer to Table 36 above). It was identified that *Hits* were recognised more than *Distractors* on Trial 6 ($t(72) = 7.45$, $p = .000$, partial $\eta^{2 =} .44$) (Refer to Table 36 above). It was identified that *Hits* were recognised more than *Distractors* on Trial 7 *(*$t(65) = 5.44$, $p = .000$, partial $\eta^{2 =} .31$) (Refer to Table 36 above). It was identified that *Hits* were recognised more than *Distractors* on Trial 8($t(65) = 5.59$, $p = .000$, partial $\eta^{2 =} .37$) (Refer to Table 36 above).

However, there was no significant *Trial* x *Age* interaction ($F_{pillai's}$ (9, 293) = .86, p = .602, partial $\eta^2 = .09$, power = .52). Significant interactions indicate that the main effects should be interpreted with caution. There was no significant main effect of *Age* ($F(1, 62) = 1.54$, $p = .223$, partial $\eta^2 = .05$, power =.32). However, there was a significant main effect of *Target*, with hits recognised more than distractors ($F_{pillai's}$ (1, 63) = 151.42, $p < .001$, partial $\eta^2 = .71$, power approaching 1).

There was also a significant main effect of *Trial* ($F_{pillai's}$ (7, 293) = 21.61, $p < .001$, partial $\eta^2 = .73$, power approaching 1.00). It was identified that there was a significant difference between Trial 1 and 2, with more targets recognised on Trial 2. There was a significant difference between Trials 1 and 3, with more targets recognised on Trial 3. There was a significant difference between Trials 1 and 4, with more targets recognised on Trial 4. There was a significant difference between Trials 1 and 7, with more targets recognised identified on Trial 7. There was a significant difference between Trials 1 and 8, with more targets recognised on Trial 8.

There was a significant difference between Trials 2 and 4, with more targets recognised on Trial 4. There was a significant difference between Trials 2 and 5, with more targets recognised on Trial 5. There was a significant difference between Trials 2 and 6, with more targets recognised on Trial 2. There was a significant difference between Trials 2 and 7,

with more targets recognised on Trial 7. There was a significant difference between Trials 2 and 8, with more targets recognised on Trial 8.

There was a significant difference between Trials 3 and 4, with more targets recognised on Trial 4. There was a significant difference between Trials 3 and 5, with more targets recognised on Trial 5. There was a significant difference between Trials 3 and 6, with more targets recognised on Trial 3. There was a significant difference between Trials 3 and 7, with more targets recognised on Trial 7. There was also a significant difference between Trials 3 and 8, with more targets recognised on Trial 8.

There was a significant difference between Trials 5 and 6, with more targets recognised on Trial 5. There was a significant difference between Trials 5 and 7, with more targets recognised on Trial 7. There was also a significant difference between Trials 5 and 8, with more targets recognised on Trial 8.

There was a significant difference between Trials 6 and 7, with more targets recognised on Trial 7. There was a significant difference between Trials 6 and 8, with more targets recognised on Trial 8. There was also a significant difference between Trials 7 and 8, with more targets recognised on Trial 8.

Verbal implicit memory. A mixed factorial MANOVA (Multivariate Analysis of Variance) was conducted to assess the effect of *Age* (Young Old (18-49), Middle Old (50-64), and Older Adults (65+)), and *Frequency* (High vs. Low) on *Accuracy*. α was set at .05 apriori.

There was no significant *Age* x *Frequency* interaction (F_{wilks} (2, 63) = 1.46, p = .240, partial η^2 = .04, power = .31). As the interaction was not significant, each of the main effects was considered. There was a significant main effect of *Frequency*, with high frequency words completed more accurately than low frequency words (F_{wilks} (1, 63) = 286.31, p < .001, partial η^2 = .82, power approaching 1). It was identified that high frequency words were

completed more accurately than low frequency words. However, there was no significant main effect of *Age* ($F(2, 63) = 2.27$, $p = .111$, partial $\eta^2 = .07$, power = .45). Although there was no significant effect of *Age*, there is evidence of a downward trend from young to older adults (Refer to Table 37 below). A polynomial contrast was also conducted on *Age.* Although there was no significant quadratic decline ($p = .859$), the linear contrast was significant ($p = .034$). This suggests there is some evidence of a monotonic decline.

Table 37

Average Number of High and Frequency Words Correct for Young Old, Middle Old, and Older Adults

	Age Group		
	Young Old *M* *(sd)*	Middle Old *M* *(sd)*	Older Adults *M* *(sd)*
High Frequency Words	10.46 *(3.02)*	9.10 *(2.64)*	8.52 *(2.32)*
Low Frequency Words	3.71 (2.12)	3.59 (1.83)	3.05 (2.62)

Correlational investigation of Age and Accuracy

Although no main effect of *Age* was identified, there was some indication of a linear downward trend from young to older adults. Therefore, an exploratory analysis was conducted to assess whether there was a relationship between *Age* and *Accuracy*. α was set at .025 apriori. As the effect of *Frequency* was not the main focus in the current study, high and low frequency accuracy scores were combined using mean centering.[19] Moreover, as there was a main effect of frequency and a large variance in scores, it is thought this method would produce a more reliable measure rather than obtaining the average or sum of high and low and frequency words. When a composite measure was obtained, it was found that there was a

[19] The average score for the entire cohort was subtracted from each individual's obtained score.

significant negative correlation between *Age* and *Accuracy (r* = -.28, *n* = 66, *p* = .012). This suggests that a lack of power may explain why a significant effect of *Age* on *Accuracy* was not obtained in the initial analysis. In addition, it suggests that an increase in age is associated with a decrease in accuracy and provides some evidence of a decline in verbal implicit memory.

Latency. A mixed factorial MANOVA (Multivariate Analysis of Variance) was conducted to assess the effect of *Age* (Young Old (18-49), Middle Old (50-64), Older Adults (65+) and *Frequency* (High vs. Low) on *Latency*. α was set at .05 apriori. As we were only interested in assessing implicit memory decline, the new words which acted as distractors were removed prior to analysis.

There was a significant *Age* x *Frequency* interaction ($F_{pillai's}$ (2, 63) = 7.57, p = .001, partial η^2 = .19, power = .94). To assess the effect of *Age* on levels of *Frequency*, a series of univariate ANOVAs were conducted. α was set at .05 apriori. There was a significant effect of *Age* on *Latency to Complete High Frequency Words*, with older adults slower to complete high frequency words than young and middle old adults (F(2, 63) = 14.87, p < .001, partial η^2 = .32, power approaching 1). To investigate group differences between *Age*, a series of post hoc analyses were conducted using *Tukey's HSD* with α = .05. Tukey's test was used, as it is a moderately conservative post hoc to control for familywise error rate over entire sets of pairwise comparisons (Keppel & Wickens, 2004). There was a significant difference between the young and older adults, with older adults slower to complete high frequency words than young adults (Refer to Table 38 below). In addition, there was a significant difference between the young and older middle old adults, with older adults slower to complete high frequency words than middle old adults (Refer to Table 38 below). However, was no significant difference between young and middle old adults (Refer to Table 38 below).

Table 38

Average Latency (ms) for High and Low Frequency Words for Young Old, Middle Old, and Older Adults

	Age Group		
	Young Old *M* *(sd)*	Middle Old *M* *(sd)*	Older Adults *M* *(sd)*
High Frequency Words	2228[a] (867)	3048[b] (902)	4318 (1867)
Low Frequency Words	2767[a] (1219)	3487[b] (1278)	7441 (4713)

NB: a – Difference between young and older adults, b – Difference between middle and older adults

In addition, there was a significant effect of *Age* on *Latency to Complete Low Frequency Words*, with older adults slower to complete low frequency words than young and middle old adults ($F(2, 63) = 16.96$, $p < .001$, partial $\eta^2 = .35$, power approaching 1). To investigate the differences between *Age*, a series of post hoc analyses were conducted using *Tukey's HSD* with $\alpha = .05$. There was a significant difference between the young and older adults, with older adults slower to complete low frequency words than young adults (Refer to Table 38 above). In addition, there was a significant difference between middle and older adults, with older adults slower to complete low frequency words than middle old adults (Refer to Table 38 above). However, was no significant difference between young and middle adults (Refer to Table 38 above).

Significant interactions indicate that the main effects should be interpreted with caution. There was a significant main effect of *Age*, with older adults slower to complete words than young and middle old adults ($F(2, 63) = 21.68$, $p < .001$, partial $\eta^2 = 40$, power approaching 1). It was identified that older adults took significantly longer to complete the words than both younger and middle old adults. There were no significant differences between young and middle old adults or middle and older adults. In addition, there was a

significant main effect of *Frequency*, with low frequency words completed slower than high frequency words ($F(1, 63) = 18.52$, $p < .001$, partial $\eta^2 = .23$, power = .99). It was identified that low frequency words took longer to complete than high frequency words.

Again, there is evidence of a downward trend from young to older adults. For high frequency words, there is significance for *Age* on the linear contrast ($p < .001$) but not for the quadratic contrast (p = .511). However, on the low frequency words, both linear and quadratic functions are significant ($p < .001$ and $p = .036$ respectively).

Explicit memory. A ONEWAY between groups univariate analysis of variance (ANOVA) was run to assess the effect of *Age* (Young Old (18-49), Middle Old (50-64), and Older Adults (65+)) on *Mean Span.* α was set at .05 apriori. There was an effect of *Age* on *Mean Span*, with older adults recalling fewer digits than younger adults ($F(2, 63) = 6.82$, $p < .001$, partial $\eta^2 = .18$, power = .91). Post hoc analysis was conducted using *Tukey's HSD* ($\alpha = .05$). Tukey's test was used, as it is a moderately conservative post hoc to control for familywise error rate over entire sets of pairwise comparisons (Keppel & Wickens, 2004). There was a significant difference between young and older adults with older adults recalling fewer digits than young adults (Refer to Table 39 below). However, there were no significant differences between middle old and older adults or young and middle old adults (Refer to Table 39 below).

Table 39

Mean Span and Latency (ms) by Age Group: Young Old, Middle Old, and Older Adults

Span and Latency Variables	Age Group		
	Young Old *M* *(sd)*	Middle Old *M* *(sd)*	Older Adults *M* *(sd)*
Mean Span	7.25[a] *(1.08)*	6.98 *(1.24)*	6.01 *(1.19)*
Mean Latency	6982 *(1026)*	7401 *(716)*	7367 *(1201)*

NB: a – Young different from older adults

Latency. A ONEWAY between groups univariate analysis of variance (ANOVA) was also run to assess the effect of *Age* (Young Old (18-49), Middle Old (50-64), and Older Adults (65+)) on *Mean Latency.* α was set at .05 apriori. There was no significant difference effect of *Age* on *Mean Latency* ($F(2, 63) = 1.25$, $p = .294$, partial $\eta^2 = .04$, power = .26) (Refer to Table 39 above).

Discussion

From the research (e.g., Light et al., 1986; Spaan & Raaijmakers, 2011), there is evidence to suggest that memory for implicit material may remain preserved. Therefore, it was predicted that no age differences would be identified on the implicit memory measures.

From the measure of non-verbal implicit memory, there was a significant age by target interaction. However, when the interaction was split by target, it was found that older adults had similar performance to young and middle old adults on the recognition of hits and distractors. As no decline was observed in hit recognition, this provides some evidence that non-verbal implicit memory remains preserved from aging. This is contrary to the research of Shum et al. (1999) who found older adults had significantly less target recognition than younger adults. A significant three way-interaction between age, trial and target was also

observed. However, when the data was split by age and target, it was found that all groups increased in hit recognition across the eight trials. This suggests that the all cohorts, including the older adults, showed learning over trials. In addition, all groups increased in distractor recognition over trials. This suggests all cohorts were also more likely to learn distractors as well as hits.

Older adults also had similar accuracy to the younger cohorts on the stem completion task, the measure of verbal implicit memory. This might suggest that both younger and older adults had activation of relevant networks and were able to complete the word stems successfully. Moreover, it also suggests that older adults had sufficient encoding of the material despite not being instructed explicitly to learn the material. This provides some indication that implicit memory of a verbal nature also remains preserved from aging. Despite the lack of finding a significant age effect, there was some indication of a general downward trend in accuracy from younger to older adults. Through correlational analysis, it was identified that accuracy was negatively associated with age. Although no significant effect of age was identified on the main analysis, this might be attributed to lack of power. Therefore, it is possible that differences between cohorts may have been detected with a larger sample. Moreover, there was an effect of frequency and that high frequency words were identified more accurately than low frequency words. This might suggest that low frequency words would be more effective in the detection of age related cognitive decline.

Although no significant differences between cohorts on accuracy were identified, there was an effect of age on latency. Of interest, there was an age by frequency interaction. When the interaction was split by frequency, it was identified that older adults were significantly slower on high and low frequency words than young and middle old adults. On the high frequency word latency data there was evidence of a linear decline. However, on the low frequency words there was evidence of an accelerated decline in the older adults. Again,

this provides some indication that low frequency words are more effective in the detection of age related cognitive decline. As older adults did not decline on accuracy but had an increase in latency, this provides evidence for the *cognitive reserve hypothesis.* The *cognitive reserve hypothesis* claims that as direct pathways to knowledge become impaired, older adults are able to compensate by using redundant pathways (Stern, 2009). Subsequently, the use of alternative pathways results in higher latencies in the retrieval of information. As there is an increase in latency but no apparent accompanying decrease in accuracy, this also provides some evidence of dissociation between accuracy and latency.

Consistent with the second and third studies, older adults had significantly lower span than younger adults. This provides some evidence of explicit memory decline. It is possible that the older adults are making semantic associations from numbers they have previously stored in memory. As the decrease in span is small (average of 1 digit), this suggests that explicit memory in the form of span is not as severe compared to other domains of cognition. In addition, there was no significant effect of age on latency.

A further aim was to assess whether age related cognitive decline is modular or generalised. As decline was found in explicit memory but implicit memory remained preserved, this provides some evidence for dissociation of memory processing. It also provides support for a modular decline with increasing age. However, no dissociation between verbal and non-verbal implicit memory processes was observed.

Overall Conclusions

From the non-verbal implicit memory measure, older adults were not significantly different from younger adults on hit recognition. This provides some evidence that implicit memory for non-verbal material remains preserved. On the verbal implicit memory measure, it was identified that there was no significant effect of age on accuracy. However, correlational analysis identified that age was negatively associated with accuracy. This

provides some evidence of age related decline in verbal implicit memory. As the decline in accuracy identified was exploratory, it was inferred that verbal implicit memory remains preserved from aging. In addition, it was identified that there was significant age related decline in latency, with older adults taking longer to complete high and low frequency words than young and middle old adults. This finding provides support for the *cognitive reserve hypothesis.* On the explicit memory measure, there was evidence of an age related decline on accuracy but not for latency.

As decline in explicit memory was observed but implicit memory remained preserved, this provides some evidence of dissociation between implicit and explicit memory processes. It also provides further support of modular decline with increasing age. In the next chapter, the findings from all studies and their implications will be discussed.

Chapter 8: Discussion

The current thesis aimed to clarify both the nature and onset of age related cognitive decline. Prior research has been equivocal as to whether there is an overall degradation of cognitive functioning or whether aspects of cognition appear to decline more rapidly than others. A series of five studies was conducted to assess whether age related cognitive decline is generalised or modular. In addition, it has been unclear when cognitive decline begins. There is some evidence that decline may begin as early as the second decade of life. Therefore, the current research also investigated cognitive performance in younger adults to determine whether there is evidence of incipient decline. The deeper understanding of cognitive decline that has arisen from the current research should also allow for more effective treatment or intervention pathways and also aid in the development of more sensitive instrumentation in the detection of cognitive decline. The findings are presented and discussed with conclusions in the following sections.

In the first study age related decline in executive functioning was observed. From the Wisconsin Card Sorting Test, middle old adults were found to make significantly more perseverative errors than younger adults. However, this was not the case in the younger adults. Although older adults did not make more perseverative errors, there was evidence of variability in the sample. When the older adults were divided based on functional performance, it was found one cohort showed evidence of perseveration. This provided some evidence for age related decline in shifting. From the Stroop Test there was evidence of a linear decline with age on neutral words. In addition older adults were found to be slower in the identification of semantically incongruent words than young and middle old adults. This provides some evidence of deficit in response inhibition. That is that incongruent stimuli troubled the oldest participants more than any other group. As both instruments were capable of detecting differences in the middle old adults, this suggests they have utility in the

detection of incipient age related cognitive decline. Using a digit span task, there was no evidence of decline in short-term memory performance. This finding provides some evidence that areas of cognition are declining faster than others.

It was investigated whether emotion recognition could provide insight into the aging process. It was assessed whether changes in emotion recognition could be attributed to a decline in verbal or nonverbal memory. It was found that there was some evidence of a decline in emotion recognition in the older adults. However, this was only found for anger, surprise and fear recognition. Further, there was evidence of age related decline in verbal memory (span). This could indicate that verbal memory has a common element in the ability to recognise emotional stimuli. However, non-verbal memory (memory for faces) was found to remain intact. This provided some evidence that memory for the whole face remains relatively intact in aging.

Although there was no apparent decline in non-verbal memory in the form of the memory for faces task, this finding did not exclude the possibility that other types of visual processing are breaking down, which may be expressed in difficulty for processing specific features of the face. Another possibility is that neural areas involved in the recognition of emotion are breaking down and this might be expressed as difficulty in the processing of emotional content.

Therefore, it was also investigated whether emotion recognition could be attributed to a decline in either visual or emotion processing. However, when emotion recognition was assessed in the third study, it was found that recognition of all emotions other than anger was found to remain preserved in the older adults. This suggests emotion recognition is not a reliable indicator of age related cognitive decline. There was no effect of age on the valence-priming task, which also provides some evidence for preservation of emotion processing.

However, there was some indication that the older adults had difficulty in the processing of specific features and were more likely to process the totality of the stimuli.

Although the tendency to process the totality was found in relation to visual processing, this may be an indication that cognitive decline in older adults is reflected by decline in the ability to process the fine details of specific stimuli. Memory is also an area of functioning where older adults may have difficulty in processing specific detail. An alternative explanation of the apparent decline in the processing of specific details may be the indirect consequence of an age related change in memory. Therefore, semantic memory processes were investigated to assess whether older adults remember the specific detail of the stimuli or are more likely to remember the general idea or the "gist".

This was supported, as it was found that older adults were more likely to recognise semantically related items on both verbal and non-verbal gist tasks. Both middle and older adults recognised significantly more lure items than younger adults on the verbal gist task. In addition, older adults also recognised significantly fewer target items than the younger and middle old adults on the non-verbal gist task. This provides evidence that older adults are remembering the general idea, or gist. An intriguing finding was the younger adults were found to be the least accurate of the three cohorts in recognising the target on the verbal gist task. This may be indicative of a sampling bias. Alternatively, it could indicate a task demand characteristic in that the younger adults found the task too easy or trivial. Overall there is evidence to suggest that older adults have more of a propensity to make gist errors. There was also some indication that remembering the general idea may occur earlier than expected as middle old adults also had a tendency to make semantically related errors on the verbal gist task.

Further, it was investigated whether older adults decline on implicit and explicit memory processes. Although older adults were found to perform similarly to the younger

cohorts on the stem completion task (verbal implicit memory), through an exploratory analysis there was some indication of decline. It is possible that differences may have been detected with a larger sample. In addition, no age differences on the non-verbal implicit memory measure were observed. Again, there was evidence of decline in span, which was used as the explicit memory measure in the study. From the main analysis, there is evidence of dissociation between implicit and explicit memory processes; this provides further support of modular decline with increasing age (Refer to Table 40 below for a summary of results for studies one to five).

Table 40

Domains Measured and Results Obtained for Studies One to Five

Study	Domains Measured	Part of Test	Accuracy/Latency	Decline
One		Perseverative errors (WCST)	Accuracy	Middle old adults made more perseverative errors than young old adults
	Executive functioning - shifting	Perseverative runs		No differences in age
		Perseverative responses		No differences in age
		Total errors		Monotonic decline
		Unique errors		Older adults more unique errors than middle old adults
		Correct responses		Monotonic decline
		Non-perseverative errors		Older adults made more non-perseverative errors than young and middle old adults
		Number of trials		No differences in age
		No of trials to complete 1^{s} cat		Middle old adults more trials to complete first category than young adults
	Executive functioning - response inhibition	Semantically incongruent words (VST) Neutral Words	Latency	Older adults slower to identify semantically incongruent words than young and middle old adults Monotonic decline
	Short term memory	Digit span	Accuracy	No differences in age
	Latency	Digit span	Latency	Older adults slower to recall than young old adults
Two	Emotion recognition	Face recognition	Accuracy	Older and middle old less accurate than young adults on anger recognition, older adults less accurate than middle old on fear recognition, older adults less accurate than young and middle adults on surprise recognition
	Verbal memory	Digit span	Accuracy	Decline in span from young to older adults
	Nonverbal memory	Memory for faces		No differences in age
	Nonverbal memory	Memory for faces	Latency	Middle and older adults slower to recognise faces than younger adults.
	Verbal memory	Digit span	Latency	No differences in age

Three	Emotion recognition	Face recognition	Accuracy	Anger – Older adults less accurate than young and middle old adults
	Emotion recognition	Face recognition	Latency	Older adults slower than young and middle adults except on disgust and surprise. Middle old slower than young adults on all emotional states
	Emotion processing	Valence priming	Accuracy Latency	No differences in age No effect of prime but older adults slower than young adults to identify negative target faces. Older and middle old adults slower than younger adults to identify happy target faces.
	Visual processing	Facial discrimination	Accuracy	Monotonic decline on eyes and mouth right side up and normal upside down conditions
	Visual processing	Facial discrimination	Latency	Older and middle old adults slower than young adults. Older adults also slower than middle old adults
	Verbal memory	Digit span	Accuracy	Decline in span from young to older adults
	Verbal memory	Digit span	Latency	No differences in age
Four	Nonverbal gist	Pictorial stimuli recognition	Accuracy	Older adults less accurate for target pictorial stimuli than young and middle old Older adults made more semantic errors than young old and middle old adults
	Nonverbal gist	Pictorial stimuli recognition	Latency	Older adults slower than young and middle on target pictorial stimuli Older adults slower than young adults on semantically related pictorial stimuli
	Verbal gist	Word recognition	Accuracy	Younger adults less accurate than middle old and older words on target stimuli Middle and old adults recognised more semantically related stimuli than young adults
Five	Verbal implicit memory	Stem completion	Accuracy	No differences in age
	Verbal implicit memory	Stem completion	Latency	Older adults slower than young and middle old adults on high and low frequency words
	Nonverbal implicit memory	Chinese characters recognition	Accuracy	No differences in age

Potential Explanations for Results Obtained

Behaviourial. This theory would suggest that performance decrement in the older adults is from the use of behavioural strategies such as inattentiveness or lack of engagement. Alternatively, it might be that older adults are more likely to implement an intuitive prototype or model that they are able to apply easily and quickly. As a consequence, there is likely to be a decline in accuracy on cognitive tasks. There is also likely to be an accompanying decrease in reaction time when compared to the younger adults.

From the results obtained it is unlikely that this is the mechanism behind decrement in performance in the older adults. It was found older adults had similar accuracy on many tasks (e.g., memory for faces, perceptual scan, emotion recognition) to the younger cohorts. This suggests that cognitive mechanisms are still working. However, older adults were found to be consistently slower on tasks than the younger adults. This would suggest that older adults are still engaging in the task. It might also indicate that older adults are compensating by using redundant pathways, which is more consistent with the *cognitive reserve hypothesis*. From this evidence, it is unlikely that performance decrement in the older adults is a consequence of using a strategic behavioural strategy.

Generalised slowing. This theory would suggest that performance decrement in the older adults is due to an overall cognitive decline. It is possible that that this is a consequence of amyloid β build-up. This increase in amyloid β build-up may then result in disturbances of neural network activity or neuronal death (Cramer et al., 2012; Palop & Mucke, 2010). Consequently, there is likely to be a decrease in accuracy and increase in latency compared to the younger adults. Older adults were indeed found to be less accurate and slower than younger adults on the feature integration and non-verbal gist task, providing evidence for generalised slowing. However, other findings obtained do not support this argument. In the second study, older adults were found to have an increase in latency on the memory for faces

task but had similar accuracy to the younger adults. This was also found on the emotion recognition task in the third study in that although older adults had longer latencies than the younger adults, they were still able to accurately recognise emotional stimuli. In the fifth study, older adults were also found to have similar accuracy on the stem completion task but again took longer than the younger adults. Again, this would argue against the idea of a generalised slowing and an overall degradation of cognitive function.

Cognitive reserve. The *cognitive reserve hypothesis* proposes the idea of differential preservation in cognition and that individuals who have higher levels of cognitive reserve (the brains ability to actively cope and function after damage) are more likely to maintain higher levels of cognitive performance. It is thought that factors such as higher IQ may act as a protective buffer and hence delay the onset of decline. Therefore, a relative preservation in accuracy for the older adults could be expected. However, there might also be an increase in latency due to the use of redundant pathways in the retrieval of information.

As previously mentioned, it was found that older adults had similar accuracy, however, were consistently slower on tasks compared to the younger adults. This finding was consistent throughout the studies. This would suggest that cognitive mechanisms are reasonably intact. The finding that older adults are still able to perform the task reasonably well, despite taking a longer period of time would suggest the recruitment of different neural areas and secondary pathways in the retrieval of information (Stern, 2009). From the results obtained, it was concluded that the *cognitive reserve hypothesis* is the most viable explanation of decline in the older adults.

Argument for Modular Decline

There was evidence of age related decline in some areas of cognitive functioning (e.g., visual processing). However, in other areas (e.g., non-verbal memory), no differences in age were observed. In addition, although older adults were consistently found to decline on

the span task, the decrease was only small (average of one digit). The finding of a slight decline in short-term memory in the presence of a more rapid decline of executive functioning and semantic memory processes also supports a modular decline. These findings challenge the notion of a generalised decline and suggest that specific sub-systems may decline independently.

Moreover, there was evidence of dissociation within all studies. In the first study dissociation between executive functioning and short-term memory was found. In the second study dissociation of verbal and non-verbal memory processes was found. In the third study dissociation between visual and emotion processing was found. In the fourth study dissociation between verbal and non-verbal representations was found. In the final study dissociation between implicit and explicit memory processing was found. Further, dissociations between accuracy and latency on the memory for faces task (non-verbal memory) in the second study, emotion recognition and perceptual scanning tasks in the third study, and stem completion task in the final study were observed. In addition, evidence of dissociation was consistently found between accuracy and latency on the digit span task. It could be argued that finding some areas to decline and not others may reflect insensitive instrumentation. However, there is a strong argument to challenge the notion that cognitive decline affects the entire brain.

Limitations and Conclusion

One key limitation identified was the type of sampling used to recruit participants for each of the studies. Due to the need for a population with particular characteristics, a purposive sampling technique was used. Although purposive sampling is not as effective as stratified random sampling and may not be representative of the population, this technique is useful in gathering participants that share particular characteristics (Babbie, 2007). In this series of studies, the particular characteristic of interest was independent living healthy older

adults. The younger adults were also recruited through convenience sampling and provided credit for participation in the study. Future research could consider using a stratified random sampling technique to ensure that the participants are representative of the population.

A second limitation was variation in testing environments. Due to a lack of dedicated lab space at the institution the study was conducted, the participants were tested in a variety of environments including offices and homes. Having all participants tested in the same lab space may have produced more reliable results and ensured that environmental factors such as noise were controlled for. However, it is also possible that there may have been a performance decrement associated with context, as participants would be unfamiliar with a lab setting. Therefore, by testing people in their own environment, we are likely to have captured performance consistent with their day-to-day functioning.

A third limitation was the lack of use of a clinical sample. It could have been beneficial to assess how older adults' performance compared to a sample with Alzheimer's disease. Future research could consider implementing a clinical sample to compare level of cognitive decline across cohorts.

A fourth limitation was there was a gender bias with males being under represented in the studies. Again due to the need for a sample with particular characteristics, it was not possible to have a balance of males and females. Consequently, this may suggest the results obtained in the study reflect what is happening in the aging brain of females rather than males. Future research should include more males to clarify whether the mechanisms of aging obtained in the thesis are consistent across both genders.

A final limitation was that a longitudinal design was not implemented in the current study. Although it would have been beneficial to observe age related changes over a period of time, it is important to have measures that are adequate in the detection of cognitive decline. As part of the research was finding measures that are most adequate in the detection of age

related cognitive decline, this type of design was unable to be implemented. Future research could consider assessing the sample cohort of individuals to assess level of decline over a longer timeframe.

The current thesis has identified that age related decline appears to be modular in nature and suggests that some areas of cognitive functioning (e.g., verbal gist) are more vulnerable to decline and thus may be useful indicators for detection than others. The thesis demonstrates how difficult it is to sort through all confounding variables (e.g., medication, effects of health issues such as heart and stroke) that might influence the likelihood of cognitive impairment occurring or worsening. The finding that age related decline is modular has potential implications for treatment. If decline affects specific subsystems, then perhaps interventions can be tailored to treat these areas of cognitive functioning.

The thesis has also identified evidence of incipient decline, commencing as early as young adulthood. Previously it had been identified that decline occurred after the age of 65; with some other evidence to suggest that it may begin as early as the second decade of life (e.g., Murre et al., 2013). The thesis has identified incipient decline in the middle old adults aged 50 to 64, and some evidence of decline in the younger adult (18-49) cohort. In the fourth study that assessed memory for specific and general detail, young adults were found to recognise fewer target stimuli than middle and older adults on the verbal gist task. These findings (in the fourth study) were inconsistent with results obtained in the other studies of the thesis. Explanations include there was a sampling bias and damaged cohort. Alternatively, the differences could indicate a task demand characteristic in that the younger adults found the task too easy or trivial. As these findings were inconsistent further study is required in this area.

The former explanation could suggest that decline in memory for specific material occurs as early as the second decade in life. Further, this would support recent research (e.g.,

Murre et al., 2013) that age related cognitive decline could occur much earlier than previously documented. The finding that decline can be detected earlier in life also has implications for treatment intervention. It has been claimed that intervention might be more effective if decline is detected before initial symptoms appear (AAAS, 2012). This could suggest that pharmacological interventions (e.g., cholinesterase inhibitors) should be implemented once symptoms can be detected. Behavioural strategies such as exercising and staying mentally active (e.g., doing crossword puzzles, reading books and newspapers and engaging in regular physical activity) would also be encouraged early in life.

This thesis has identified several instruments that appear to be sensitive to early changes in cognition which may be indicative of incipient decline. The instruments identified to be most useful in early detection of cognitive decline among those used were the Victoria Stroop Test, the Wisconsin Card Sorting Test, the distorted facial recognition task and the verbal gist task. If the findings of this study are replicated by future research then one might consider packaging these instruments as a test battery and retesting on larger populations to assess whether these have wider utility in detection of early symptomatology. Earlier detection and knowledge of the type of decline evidenced provides an option for perhaps targeted treatment plans. This is becoming increasingly important as disease models for the onset of dementia suggest effective pharmacological treatments may be coming available.

It was further identified that cognitive reserve might be masking decline on particular tasks. A consistent finding throughout the studies was that older adults were as accurate as younger adults but took longer to retrieve information. It is thought that cognitive reserve protective factors may potentially act as a buffer and slow the onset of decline, again suggesting that these reserve factors should be implemented as early in life as possible. Bilingualism or multilingualism has been identified as a protective factor, delaying the onset

of decline in cognitive functioning (e.g., Craik, Bialystok, & Freedman, 2010; Schweizer, Ware, Fischer, Craik, & Bialystok, 2012). Antoniou, Gunasekera, and Wong (2013) argue that learning a foreign language will contribute to levels of cognitive reserve and act as a safeguard against cognitive decline. Gold, Johnson, and Powell (2013) found that older individuals who were bilingual had similar levels of cognitive functioning to those who only spoke one language despite having significantly lower white matter integrity. This suggests that cognitive reserve may preserve functioning despite evidence of structural decline. For example, a person who is multilingual may have more than one association for the word 'dog'. Therefore, if one pathway is damaged, they may still be able to retrieve the association through another, perhaps less direct route, unlike an individual who speaks one language who may only have one connection. This might suggest that there is some utility in teaching children a second language at school, to build cognitive reserve. Other cognitive reserve factors (e.g., education) should be also encouraged as early in life as possible.

The current study has provided insight into the nature and onset of age related cognitive decline, as well as outlining a potential pathway for the development of further research into the area of aging in the future.

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List of Appendices

Appendix A. Neuropsychological Measures used in Assessing Cognitive Decline

Mini Mental State Examination (MMSE; Folstein et al., 1975)

The Mini Mental State Examination (MMSE; Folstein et al., 1975) is a neuropsychological measure designed for physicians to assess cognitive functioning. The instrument assesses the areas of attention, calculation, orientation, registration, recall, and language. Administration time of the instrument is approximately 10 minutes. The Mini Mental State Examination has been considered the gold standard of cognitive assessment for physicians based on its brevity and simplicity to use. On the other hand, the instrument has been criticised as being an insensitive instrument that does not adequately assess executive functioning (Rahman & Gaafary, 2009; Zadikoff et al., 2008). It also has a bias toward verbal items, and is influenced by education level (Uhlmann & Larson, 1991; Xu, Meyer, Thornby, Chowdhury, & Quach, 2002). In addition, the Mini Mental State Examination has been found to have low sensitivity and predictive value in the detection of early cognitive decline (Kaufer et al., 2008; Luis, Keegan, & Mullan, 2009; Mitchell, 2009; Tang-Wai et al., 2003). Moreover, Wind et al. (1997) found only four questions were able to differentiate dementia from non-dementia, suggesting that the instrument as a diagnostic utility is limited.

Montreal Cognitive Assessment (MoCA; Nasreddine et al., 2005)

The Montreal Cognitive Assessment (MoCA; Nasreddine et al., 2005) is a neuropsychological measure used in the assessment of cognitive functioning. The instrument contains 30 items assessing executive functioning, visuospatial abilities, attention, concentration, language, memory and orientation. Administration time of the instrument is approximately 10 minutes (Nasreddine et al., 2005). Studies (e.g. Lee et al., 2008; Luis et al., 2009; Nasreddine et al., 2005; Zadikoff et al., 2008) have found the Montreal Cognitive Assessment to provide a more sensitive diagnosis than the Mini Mental State Examination

(MMSE; Folstein et al., 1975). The instrument has also been shown to have excellent sensitivity and specificity in the detection of mild cognitive impairment (Nasreddine et al., 2005). However, the instrument does not provide a comprehensive depiction of functioning as the instrument only contains few items from each cognitive domain. Moreover, the instrument does not assess latency of responding.

Clock Drawing Test (CDT; Goodglass & Kaplan, 1983)

Different implementations of the Clock Drawing Test (CDT; Goodglass & Kaplan, 1983) have been used in the assessment of cognition; however, the main principles of the test are still the same. The Clock Drawing Test requires the individual to draw designated times on clock faces and points are awarded based on the correct drawing of the minute and hour hands. The task despite seeming simple, assessing comprehension, planning, visual memory, visuospatial abilities, concentration, motor execution, numerical knowledge, abstract thinking, inhibition, concentration and frustration tolerance (Shulman, 2000). However, the instrument is limited in that education, age and mood can impact performance on the test. In addition, it is claimed that the test may have limited utility in the detection of early cognitive decline (Agrell & Dehlin, 1998).

Mini Cog (Borson et al., 2003)

The Mini Cog (Borson et al., 2003) is a brief measure that assesses memory and the same domains associated with the Clock Drawing Test. Administration time of the task is approximately 2-4 minutes. The Mini Cog consists of a 3-word memory task and clock drawing test, which provides either a demented/not-demented diagnosis. The instrument has been found to have limited sensitivity and predictive value in the detection of mild cognitive impairment (Kaufer et al., 2008).

Florida Brief Memory Screen (FBMS; Loewenstein et al., 2009)

The Florida Brief Memory Screen (FBMS; Loewenstein et al., 2009) uses a 15-item memory task with three different semantic categories to assess memory. Administration time of the task is approximately 3-4 minutes. The subject is informed of the categories before administration and is presented the words separately for four seconds and then asked to read the category aloud. After the administration of the words, the subject is then required to recall the words from the list that was presented (Loewenstein et al., 2009). Although the instrument has been shown to be a reliable measure in the detection of Alzheimer's disease, it was found to have lower sensitivity and specificity in the detection of mild cognitive impairment (Loewenstein et al., 2009).

CogState (Cog-state.com, 2010)

The CogState (Cog-state.com, 2010) is a computerised inventory designed to measure attention, processing speed, memory, decision-making and visual tracking. The inventory is accessed from the Internet and takes approximately 20 minutes to complete. The Cogstate contains eight tasks that are based on a pack of playing cards. One of the core strengths of the Cog-State is that it is computerized and able to provide accurate response times (De Jager et al., 2009). However, the Cogstate was found to be limited in discriminating individuals with mild cognitive impairment from healthy controls (Hammers et al., 2012). This suggests that the instrument is not sensitive in the early detection of cognitive decline.

7 Minute Screen (7MS; Solomon et al., 1988)

The 7 Minute Screen (7MS; Solomon et al., 1988) is a brief instrument assessing orientation, memory, visuospatial abilities and language. The instrument involves the administration of 4 brief tests, which include Enhanced Cued Recall, Temporal Orientation, and Clock Drawing Test. The battery of tests was selected based on their ability to be able to distinguish between differences in cognition that accompany normal aging and Alzheimer's

disease. The 7 Minute Screen (Solomon et al., 1988) has been found to have utility in the detection of Alzheimer's disease, however, the instrument has not been validated for detection of mild cognitive impairment (Nasreddine et al., 2005).

Kokmen Short Test of Mental Status (Kokmen et al., 1987)

The Kokmen Short Test of Mental Status (Kokmen et al., 1987) is a brief measure that assesses orientation, attention, learning, arithmetic, abstraction, information, and construction. Administration of the instrument is approximately 5 minutes. Although the instrument has utility in the detection of Alzheimer's disease, the instrument has not been validated for mild cognitive impairment (Nassredine et al., 2005).

Memory Impairment Screen (MIS; Buschke et al., 1999)

The Memory Impairment Screen (MIS; Buschke et al., 1999) uses a 4 item delayed and cued recall test of memory impairment used in the detection of dementia. To improve detection rates, the MIS implements controlled learning to ensure attention, encourage semantic processing as well as to optimize encoding specificity (Buschke et al., 1999). Although the instrument has some utility in the detection of Alzheimer's disease, it has not been validated for mild cognitive impairment (Nassredine et al., 2005).

Appendix B. Words Presented in Priming Phase of Perceptual Scan (Study 3)

Negative Words	Positive Words
Pain	Happy
Sad	Excited
Stressed	Joyful
Mad	Relaxed
Nervous	Brave
Tense	Calm
Anxious	Peaceful
Pessimistic	Laughing
Heartbroken	Content
Dejected	Blissful
Melancholy	Upbeat
Sorry	Lucky
Mournful	Fortunate
Despairing	Whimsical
Gloomy	Graceful
Afraid	Optimistic
Fearful	Good
Shaky	Admirable
Worried	Valuable
Concerned	Superior
Scared	Worthy
Despairing	Honourable
Gloomy	Satisfactory
Afraid	Precious
Death	Righteous
Agony	Respect
Trauma	Innocent
Distrust	Honest
Apprehensive	Wonderful
Afraid	Optimistic
Sweaty	Cheerful

Appendix C. Words Presented in Verbal Gist Task (Study 4)

Anger – Lure	Black - Lure	Bread – Lure	Chair - Lure
Mad	White	Butter	Table
Fear	Dark	Food	Sit
Hate	Cat	Eat	Legs
Rage	Charred	Sandwich	Seat
Temper	Night	Rye	Couch
Fury	Funeral	Jam	Desk
Ire	Colour	Milk	Chair
Wrath	Grief	Flour	Recliner
Happy	Blue	Jelly	Sofa
Fight	Death	Dough	Wood
Hatred	Ink	Crust	Cushion
Mean	Bottom	Slice	Swivel
Smooth	Bed	Fast	Hard
Bumpy	Rest	Lethargic	Light
Road	Awake	Stop	Pillow
Tough	Tired	Listless	Plush
Sandpaper	Dream	Snail	Loud
Jagged	Wake	Cautious	Cotton

Appendix D. Words Presented In Stem Completion Task (Study 5)

High Frequency Words

stand	truck	layer	wrist	angel	hedge	fancy	plain
court	shape	watch	alarm	liver	wedge	bacon	fever
dream	river	clock	magic	vents	bluff	scorn	chute
agent	lunch	apple	opera	snack	satin	notch	comic
brain	shirt	cabin	giant	guess	jolts	bliss	orbit

Low Frequency Words

commo	limey	frosh	etude	scoff	expat	phlox	bloat
kurta	flume	sulfa	savoy	ennui	baldy	drake	luger
caber	shire	meany	kugel	plumb	hokum	faker	divvy
mynah	sebum	caulk	slosh	vireo	funny	bronc	shire
morro	phial	civvy	perms	faery	doyen	sicko	scrum

Appendix E. SPSS Output

Wisconsin Card Sorting Test
Error

Descriptive Statistics

	group	Mean	Std. Deviation	N
totalerrors	.00	27.09	9.645	35
	1.00	42.25	14.374	20
	2.00	61.05	19.102	20
	Total	40.19	19.735	75
perserrors	.00	16.80	5.718	35
	1.00	25.35	11.250	20
	2.00	24.20	17.879	20
	Total	21.05	12.075	75
nonperserrors	.00	10.23	6.040	35
	1.00	16.90	7.826	20
	2.00	36.85	27.987	20
	Total	19.11	18.902	75
unique	.00	1.06	1.999	35
	1.00	.45	.686	20
	2.00	2.05	2.856	20
	Total	1.16	2.099	75

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[e]
Corrected Model	totalerrors	14797.944[a]	2	7398.972	37.994	.000	.513	75.987	1.000
	perserrors	1200.437[b]	2	600.218	4.507	.014	.111	9.013	.753
	nonperserrors	9152.625[c]	2	4576.313	19.061	.000	.346	38.122	1.000
	unique	26.294[d]	2	13.147	3.158	.048	.081	6.315	.588
Intercept	totalerrors	132225.602	1	132225.602	678.977	.000	.904	678.977	1.000
	perserrors	34240.286	1	34240.286	257.087	.000	.781	257.087	1.000
	nonperserrors	31836.448	1	31836.448	132.602	.000	.648	132.602	1.000
	unique	98.414	1	98.414	23.636	.000	.247	23.636	.998
group	totalerrors	14797.944	2	7398.972	37.994	.000	.513	75.987	1.000
	perserrors	1200.437	2	600.218	4.507	.014	.111	9.013	.753
	nonperserrors	9152.625	2	4576.313	19.061	.000	.346	38.122	1.000
	unique	26.294	2	13.147	3.158	.048	.081	6.315	.588
Error	totalerrors	14021.443	72	194.742					
	perserrors	9589.350	72	133.185					
	nonperserrors	17286.521	72	240.091					
	unique	299.786	72	4.164					
Total	totalerrors	149942.000	75						
	perserrors	44033.000	75						
	nonperserrors	53819.000	75						
	unique	427.000	75						
Corrected Total	totalerrors	28819.387	74						
	perserrors	10789.787	74						
	nonperserrors	26439.147	74						
	unique	326.080	74						

a. R Squared = .513 (Adjusted R Squared = .500)

b. R Squared = .111 (Adjusted R Squared = .087)

c. R Squared = .346 (Adjusted R Squared = .328)

d. R Squared = .081 (Adjusted R Squared = .055)

e. Computed using alpha =

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[d]
Intercept	Pillai's Trace	.914	184.014[b]	4.000	69.000	.000	.914	736.056	1.000
	Wilks' Lambda	.086	184.014[b]	4.000	69.000	.000	.914	736.056	1.000
	Hotelling's Trace	10.667	184.014[b]	4.000	69.000	.000	.914	736.056	1.000
	Roy's Largest Root	10.667	184.014[b]	4.000	69.000	.000	.914	736.056	1.000
group	Pillai's Trace	.599	7.481	8.000	140.000	.000	.299	59.846	1.000
	Wilks' Lambda	.445	8.614[b]	8.000	138.000	.000	.333	68.908	1.000
	Hotelling's Trace	1.150	9.772	8.000	136.000	.000	.365	78.175	1.000
	Roy's Largest Root	1.057	18.489[c]	4.000	70.000	.000	.514	73.957	1.000

a. Design: Intercept + group

b. Exact statistic

c. The statistic is an upper bound on F that yields a lower bound on the significance level.

d. Computed using alpha =

Multiple Comparisons

Tukey HSD

Dependent Variable	(I) group	(J) group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
totalerrors	.00	1.00	-15.16*	3.912	.001	-24.53	-5.80
		2.00	-33.96*	3.912	.000	-43.33	-24.60
	1.00	.00	15.16*	3.912	.001	5.80	24.53
		2.00	-18.80*	4.413	.000	-29.36	-8.24
	2.00	.00	33.96*	3.912	.000	24.60	43.33
		1.00	18.80*	4.413	.000	8.24	29.36
perserrors	.00	1.00	-8.55*	3.235	.027	-16.29	-.81
		2.00	-7.40	3.235	.064	-15.14	.34
	1.00	.00	8.55*	3.235	.027	.81	16.29
		2.00	1.15	3.649	.947	-7.58	9.88
	2.00	.00	7.40	3.235	.064	-.34	15.14
		1.00	-1.15	3.649	.947	-9.88	7.58
nonperserrors	.00	1.00	-6.67	4.343	.280	-17.07	3.72
		2.00	-26.62*	4.343	.000	-37.02	-16.23
	1.00	.00	6.67	4.343	.280	-3.72	17.07
		2.00	-19.95*	4.900	.000	-31.68	-8.22
	2.00	.00	26.62*	4.343	.000	16.23	37.02
		1.00	19.95*	4.900	.000	8.22	31.68
unique	.00	1.00	.61	.572	.541	-.76	1.98
		2.00	-.99	.572	.199	-2.36	.38
	1.00	.00	-.61	.572	.541	-1.98	.76
		2.00	-1.60*	.645	.041	-3.14	-.06
	2.00	.00	.99	.572	.199	-.38	2.36
		1.00	1.60*	.645	.041	.06	3.14

Based on observed means.

The error term is Mean Square(Error) = 4.164.

*. The mean difference is significant at the

Wisconsin Card Sorting Test
Responding

Descriptive Statistics

	group	Mean	Std. Deviation	N
cresponses	.00	98.40	8.074	35
	1.00	85.00	13.401	20
	2.00	66.95	19.102	20
	Total	86.44	18.456	75
perserrespon	.00	42.89	6.305	35
	1.00	46.40	12.530	20
	2.00	39.75	25.835	20
	Total	42.99	15.360	75

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[d]
Intercept	Pillai's Trace	.978	1578.822[b]	2.000	71.000	.000	.978	3157.644	1.000
	Wilks' Lambda	.022	1578.822[b]	2.000	71.000	.000	.978	3157.644	1.000
	Hotelling's Trace	44.474	1578.822[b]	2.000	71.000	.000	.978	3157.644	1.000
	Roy's Largest Root	44.474	1578.822[b]	2.000	71.000	.000	.978	3157.644	1.000
group	Pillai's Trace	.522	12.700	4.000	144.000	.000	.261	50.802	1.000
	Wilks' Lambda	.488	15.298[b]	4.000	142.000	.000	.301	61.192	1.000
	Hotelling's Trace	1.027	17.975	4.000	140.000	.000	.339	71.901	1.000
	Roy's Largest Root	1.007	36.248[c]	2.000	72.000	.000	.502	72.496	1.000

a. Design: Intercept + group

b. Exact statistic

c. The statistic is an upper bound on F that yields a lower bound on the significance level.

d. Computed using alpha =

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[c]
Corrected Model	cresponses	12645.130[a]	2	6322.565	36.240	.000	.502	72.480	1.000
	perserrespon	442.894[b]	2	221.447	.937	.397	.025	1.874	.206
Intercept	cresponses	487473.175	1	487473.175	2794.132	.000	.975	2794.132	1.000
	perserrespon	129501.677	1	129501.677	547.959	.000	.884	547.959	1.000
group	cresponses	12645.130	2	6322.565	36.240	.000	.502	72.480	1.000
	perserrespon	442.894	2	221.447	.937	.397	.025	1.874	.206
Error	cresponses	12561.350	72	174.463					
	perserrespon	17016.093	72	236.335					
Total	cresponses	585597.000	75						
	perserrespon	156048.000	75						
Corrected Total	cresponses	25206.480	74						
	perserrespon	17458.987	74						

a. R Squared = .502 (Adjusted R Squared = .488)

b. R Squared = .025 (Adjusted R Squared = -.002)

c. Computed using alpha =

Multiple Comparisons

Tukey HSD

Dependent Variable	(I) group	(J) group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
cresponses	.00	1.00	13.40*	3.702	.002	4.54	22.26
		2.00	31.45*	3.702	.000	22.59	40.31
	1.00	.00	-13.40*	3.702	.002	-22.26	-4.54
		2.00	18.05*	4.177	.000	8.05	28.05
	2.00	.00	-31.45*	3.702	.000	-40.31	-22.59
		1.00	-18.05*	4.177	.000	-28.05	-8.05
perserrespon	.00	1.00	-3.51	4.309	.695	-13.83	6.80
		2.00	3.14	4.309	.748	-7.18	13.45
	1.00	.00	3.51	4.309	.695	-6.80	13.83
		2.00	6.65	4.861	.363	-4.98	18.28
	2.00	.00	-3.14	4.309	.748	-13.45	7.18
		1.00	-6.65	4.861	.363	-18.28	4.98

Based on observed means.

The error term is Mean Square(Error) = 236.335.

*. The mean difference is significant at the

Wisconsin Card Sorting Test

Trials

Descriptive Statistics

	group	Mean	Std. Deviation	N
trials	.00	125.63	4.827	35
	1.00	127.25	3.354	20
	2.00	128.00	.000	20
	Total	126.69	3.831	75
trialstocom	.00	15.49	6.857	35
	1.00	27.00	14.535	20
	2.00	19.60	21.237	20
	Total	19.65	14.644	75

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[d]
Intercept	Pillai's Trace	.999	40297.977[b]	2.000	71.000	.000	.999	80595.955	1.000
	Wilks' Lambda	.001	40297.977[b]	2.000	71.000	.000	.999	80595.955	1.000
	Hotelling's Trace	1135.154	40297.977[b]	2.000	71.000	.000	.999	80595.955	1.000
	Roy's Largest Root	1135.154	40297.977[b]	2.000	71.000	.000	.999	80595.955	1.000
group	Pillai's Trace	.164	3.218	4.000	144.000	.015	.082	12.874	.819
	Wilks' Lambda	.841	3.218[b]	4.000	142.000	.015	.083	12.873	.819
	Hotelling's Trace	.184	3.217	4.000	140.000	.015	.084	12.868	.818
	Roy's Largest Root	.144	5.195[c]	2.000	72.000	.008	.126	10.391	.814

a. Design: Intercept + group

b. Exact statistic

c. The statistic is an upper bound on F that yields a lower bound on the significance level.

d. Computed using alpha =

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[c]
Corrected Model	trials	80.025[a]	2	40.013	2.864	.064	.074	5.728	.544
	trialstocom	1687.444[b]	2	843.722	4.284	.017	.106	8.567	.730
Intercept	trials	1128310.448	1	1128310.448	80760.137	.000	.999	80760.137	1.000
	trialstocom	29980.502	1	29980.502	152.212	.000	.679	152.212	1.000
group	trials	80.025	2	40.013	2.864	.064	.074	5.728	.544
	trialstocom	1687.444	2	843.722	4.284	.017	.106	8.567	.730
Error	trials	1005.921	72	13.971					
	trialstocom	14181.543	72	196.966					
Total	trials	1204926.000	75						
	trialstocom	44838.000	75						
Corrected Total	trials	1085.947	74						
	trialstocom	15868.987	74						

a. R Squared = .074 (Adjusted R Squared = .048)

b. R Squared = .106 (Adjusted R Squared = .082)

c. Computed using alpha =

Multiple Comparisons

Tukey HSD

Dependent Variable	(I) group	(J) group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
trials	.00	1.00	-1.62	1.048	.275	-4.13	.89
		2.00	-2.37	1.048	.068	-4.88	.14
	1.00	.00	1.62	1.048	.275	-.89	4.13
		2.00	-.75	1.182	.802	-3.58	2.08
	2.00	.00	2.37	1.048	.068	-.14	4.88
		1.00	.75	1.182	.802	-2.08	3.58
trialstocom	.00	1.00	-11.51*	3.934	.013	-20.93	-2.10
		2.00	-4.11	3.934	.551	-13.53	5.30
	1.00	.00	11.51*	3.934	.013	2.10	20.93
		2.00	7.40	4.438	.225	-3.22	18.02
	2.00	.00	4.11	3.934	.551	-5.30	13.53
		1.00	-7.40	4.438	.225	-18.02	3.22

Based on observed means.

The error term is Mean Square(Error) = 196.966.

*. The mean difference is significant at the

Wisconsin Card Sorting Test
Categories

Descriptive Statistics

Dependent Variable: categories

group	Mean	Std. Deviation	N
.00	6.80	1.876	35
1.00	4.75	2.403	20
2.00	2.45	1.932	20
Total	5.09	2.712	75

Tests of Between-Subjects Effects

Dependent Variable: categories

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[b]
Corrected Model	244.047[a]	2	122.023	29.256	.000	.448	58.513	1.000
Intercept	1524.444	1	1524.444	365.501	.000	.835	365.501	1.000
group	244.047	2	122.023	29.256	.000	.448	58.513	1.000
Error	300.300	72	4.171					
Total	2490.000	75						
Corrected Total	544.347	74						

a. R Squared = .448 (Adjusted R Squared = .433)

b. Computed using alpha =

Multiple Comparisons

Dependent Variable: persruns

Tukey HSD

(I) group	(J) group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
.00	1.00	-.40	1.497	.962	-3.98	3.19
	2.00	-2.31	1.497	.277	-5.89	1.27
1.00	.00	.40	1.497	.962	-3.19	3.98
	2.00	-1.91	1.689	.497	-5.96	2.13
2.00	.00	2.31	1.497	.277	-1.27	5.89
	1.00	1.91	1.689	.497	-2.13	5.96

Based on observed means.

The error term is Mean Square(Error) = 28.537.

Wisconsin Card Sorting Test
Perseverative Runs

Descriptive Statistics

Dependent Variable: persruns

group	Mean	Std. Deviation	N
.00	2.24	2.101	35
1.00	2.64	1.944	20
2.00	4.56	9.821	20
Total	2.97	5.359	75

Tests of Between-Subjects Effects

Dependent Variable: persruns

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[b]
Corrected Model	70.868[a]	2	35.434	1.242	.295	.033	2.483	.262
Intercept	693.086	1	693.086	24.288	.000	.252	24.288	.998
group	70.868	2	35.434	1.242	.295	.033	2.483	.262
Error	2054.633	72	28.537					
Total	2785.306	75						
Corrected Total	2125.502	74						

a. R Squared = .033 (Adjusted R Squared = .006)

b. Computed using alpha =

Multiple Comparisons

Dependent Variable: persruns

Tukey HSD

(I) group	(J) group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
.00	1.00	-.40	1.497	.962	-3.98	3.19
	2.00	-2.31	1.497	.277	-5.89	1.27
1.00	.00	.40	1.497	.962	-3.19	3.98
	2.00	-1.91	1.689	.497	-5.96	2.13
2.00	.00	2.31	1.497	.277	-1.27	5.89
	1.00	1.91	1.689	.497	-2.13	5.96

Based on observed means.

The error term is Mean Square(Error) = 28.537.

Victoria Stroop Test

Descriptive Statistics

	group	Mean	Std. Deviation	N
neutralwords	.00	736.0766	117.53931	35
	1.00	963.8420	181.66480	20
	2.00	1258.8000	377.36276	20
	Total	936.2069	314.10194	75
incongruentwords	.00	908.7291	330.46733	35
	1.00	1100.9860	236.59494	20
	2.00	1600.3540	527.76430	20
	Total	1144.4309	468.00801	75

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[d]
Intercept	Pillai's Trace	.948	649.545[b]	2.000	71.000	.000	.948	1299.091	1.000
	Wilks' Lambda	.052	649.545[b]	2.000	71.000	.000	.948	1299.091	1.000
	Hotelling's Trace	18.297	649.545[b]	2.000	71.000	.000	.948	1299.091	1.000
	Roy's Largest Root	18.297	649.545[b]	2.000	71.000	.000	.948	1299.091	1.000
group	Pillai's Trace	.518	12.576	4.000	144.000	.000	.259	50.303	1.000
	Wilks' Lambda	.495	14.937[b]	4.000	142.000	.000	.296	59.746	1.000
	Hotelling's Trace	.992	17.358	4.000	140.000	.000	.332	69.434	1.000
	Roy's Largest Root	.964	34.715[c]	2.000	72.000	.000	.491	69.430	1.000

a. Design: Intercept + group

b. Exact statistic

c. The statistic is an upper bound on F that yields a lower bound on the significance level.

d. Computed using alpha =

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[c]
Corrected Model	neutralwords	3498425.333[a]	2	1749212.666	33.122	.000	.479	66.244	1.000
	incongruentwords	6139502.790[b]	2	3069751.395	21.951	.000	.379	43.902	1.000
Intercept	neutralwords	68086787.883	1	68086787.883	1289.245	.000	.947	1289.245	1.000
	incongruentwords	101364660.571	1	101364660.571	724.837	.000	.910	724.837	1.000
group	neutralwords	3498425.333	2	1749212.666	33.122	.000	.479	66.244	1.000
	incongruentwords	6139502.790	2	3069751.395	21.951	.000	.379	43.902	1.000
Error	neutralwords	3802416.956	72	52811.347					
	incongruentwords	10068828.354	72	139844.838					
Total	neutralwords	73037098.941	75						
	incongruentwords	114437493.232	75						
Corrected Total	neutralwords	7300842.289	74						
	incongruentwords	16208331.144	74						

a. R Squared = .479 (Adjusted R Squared = .465)

b. R Squared = .379 (Adjusted R Squared = .362)

c. Computed using alpha =

Multiple Comparisons

Tukey HSD

Dependent Variable	(I) group	(J) group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
neutralwords	.00	1.00	-227.7654*	64.41633	.002	-381.9217	-73.6092
		2.00	-522.7234*	64.41633	.000	-676.8797	-368.5672
	1.00	.00	227.7654*	64.41633	.002	73.6092	381.9217
		2.00	-294.9580*	72.67142	.000	-468.8697	-121.0463
	2.00	.00	522.7234*	64.41633	.000	368.5672	676.8797
		1.00	294.9580*	72.67142	.000	121.0463	468.8697
incongruentwords	.00	1.00	-192.2569	104.82275	.166	-443.1107	58.5970
		2.00	-691.6249*	104.82275	.000	-942.4787	-440.7710
	1.00	.00	192.2569	104.82275	.166	-58.5970	443.1107
		2.00	-499.3680*	118.25601	.000	-782.3693	-216.3667
	2.00	.00	691.6249*	104.82275	.000	440.7710	942.4787
		1.00	499.3680*	118.25601	.000	216.3667	782.3693

Based on observed means.

The error term is Mean Square(Error) = 139844.838.

*. The mean difference is significant at the

Digit Span
Mean Span

Descriptive Statistics

Dependent Variable: digitsrecalled2

group	Mean	Std. Deviation	N
.00	6.2286	2.06436	35
1.00	6.4417	1.84429	20
2.00	6.0083	1.46845	20
Total	6.2267	1.84672	75

Tests of Between-Subjects Effects

Dependent Variable: digitsrecalled2

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[b]
Corrected Model	1.878[a]	2	.939	.270	.764	.007	.540	.091
Intercept	2713.581	1	2713.581	779.980	.000	.915	779.980	1.000
group	1.878	2	.939	.270	.764	.007	.540	.091
Error	250.491	72	3.479					
Total	3160.222	75						
Corrected Total	252.369	74						

a. R Squared = .007 (Adjusted R Squared = -.020)

b. Computed using alpha =

Multiple Comparisons

Dependent Variable: digitsrecalled2

Tukey HSD

(I) group	(J) group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
.00	1.00	-.2131	.52283	.913	-1.4643	1.0381
	2.00	.2202	.52283	.907	-1.0310	1.4714
1.00	.00	.2131	.52283	.913	-1.0381	1.4643
	2.00	.4333	.58983	.744	-.9782	1.8449
2.00	.00	-.2202	.52283	.907	-1.4714	1.0310
	1.00	-.4333	.58983	.744	-1.8449	.9782

Based on observed means.

The error term is Mean Square(Error) = 3.479.

Digit Span
Mean Latency

Descriptive Statistics

Dependent Variable: reactiontime

group	Mean	Std. Deviation	N
.00	6.6767	1.26019	35
1.00	7.4087	.96807	20
2.00	7.6104	1.03926	20
Total	7.1209	1.19502	75

Tests of Between-Subjects Effects

Dependent Variable: reactiontime

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[b]
Corrected Model	13.355[a]	2	6.677	5.208	.008	.126	10.415	.815
Intercept	3661.038	1	3661.038	2855.162	.000	.975	2855.162	1.000
group	13.355	2	6.677	5.208	.008	.126	10.415	.815
Error	92.322	72	1.282					
Total	3908.680	75						
Corrected Total	105.677	74						

a. R Squared = .126 (Adjusted R Squared = .102)

b. Computed using alpha =

Multiple Comparisons

Dependent Variable: reactiontime

Tukey HSD

(I) group	(J) group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
.00	1.00	-.7320	.31741	.061	-1.4916	.0276
	2.00	-.9337*	.31741	.012	-1.6933	-.1741
1.00	.00	.7320	.31741	.061	-.0276	1.4916
	2.00	-.2017	.35809	.840	-1.0587	.6552
2.00	.00	.9337*	.31741	.012	.1741	1.6933
	1.00	.2017	.35809	.840	-.6552	1.0587

Based on observed means.

The error term is Mean Square(Error) = 1.282.

*. The mean difference is significant at the

Study 2

Emotion Recognition

Descriptive Statistics

	groups	Mean	Std. Deviation	N
neutral	.00	.5515	.16140	21
	1.00	.5040	.12500	21
	2.00	.5709	.21339	20
	Total	.5416	.16926	62
sad	.00	.3155	.21513	21
	1.00	.2500	.17230	21
	2.00	.1813	.13738	20
	Total	.2500	.18388	62
happy	.00	.4690	.17505	21
	1.00	.4871	.17573	21
	2.00	.3656	.19625	20
	Total	.4418	.18717	62
angry	.00	.4167	.12910	21
	1.00	.2460	.15246	21
	2.00	.1959	.09477	20
	Total	.2876	.15802	62
disgusted	.00	.1175	.10935	21
	1.00	.1270	.09402	21
	2.00	.1268	.09405	20
	Total	.1237	.09795	62
contemptful	.00	.1904	.14236	21
	1.00	.2381	.12150	21
	2.00	.2043	.09933	20
	Total	.2110	.12236	62
surprised	.00	.4247	.12889	21
	1.00	.4087	.14660	21
	2.00	.2833	.14409	20
	Total	.3737	.15151	62
fearful	.00	.0754	.10177	21
	1.00	.1350	.09314	21
	2.00	.0500	.07842	20
	Total	.0874	.09717	62

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[d]
Intercept	Pillai's Trace	.972	223.564[b]	8.000	52.000	.000	.972	1788.510	1.000
	Wilks' Lambda	.028	223.564[b]	8.000	52.000	.000	.972	1788.510	1.000
	Hotelling's Trace	34.394	223.564[b]	8.000	52.000	.000	.972	1788.510	1.000
	Roy's Largest Root	34.394	223.564[b]	8.000	52.000	.000	.972	1788.510	1.000
groups	Pillai's Trace	.781	4.248	16.000	106.000	.000	.391	67.973	1.000
	Wilks' Lambda	.353	4.445[b]	16.000	104.000	.000	.406	71.116	1.000
	Hotelling's Trace	1.455	4.638	16.000	102.000	.000	.421	74.200	1.000
	Roy's Largest Root	1.113	7.376[c]	8.000	53.000	.000	.527	59.007	1.000

a. Design: Intercept + groups

b. Exact statistic

c. The statistic is an upper bound on F that yields a lower bound on the significance level.

d. Computed using alpha =

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[i]
Corrected Model	neutral	.049[a]	2	.024	.850	.433	.028	1.699	.189
	sad	.185[b]	2	.092	2.899	.063	.089	5.798	.546
	happy	.175[c]	2	.087	2.627	.081	.082	5.254	.503
	angry	.554[d]	2	.277	16.879	.000	.364	33.758	1.000
	disgusted	.001[e]	2	.001	.062	.940	.002	.124	.059
	contemptful	.025[f]	2	.013	.838	.438	.028	1.675	.187
	surprised	.244[g]	2	.122	6.217	.004	.174	12.434	.878
	fearful	.078[h]	2	.039	4.653	.013	.136	9.307	.763
Intercept	neutral	18.210	1	18.210	632.500	.000	.915	632.500	1.000
	sad	3.839	1	3.839	120.618	.000	.672	120.618	1.000
	happy	12.028	1	12.028	361.648	.000	.860	361.648	1.000
	angry	5.075	1	5.075	309.073	.000	.840	309.073	1.000
	disgusted	.949	1	.949	95.854	.000	.619	95.854	1.000
	contemptful	2.757	1	2.757	183.164	.000	.756	183.164	1.000
	surprised	8.586	1	8.586	437.972	.000	.881	437.972	1.000
	fearful	.467	1	.467	55.365	.000	.484	55.365	1.000
groups	neutral	.049	2	.024	.850	.433	.028	1.699	.189
	sad	.185	2	.092	2.899	.063	.089	5.798	.546
	happy	.175	2	.087	2.627	.081	.082	5.254	.503
	angry	.554	2	.277	16.879	.000	.364	33.758	1.000
	disgusted	.001	2	.001	.062	.940	.002	.124	.059
	contemptful	.025	2	.013	.838	.438	.028	1.675	.187
	surprised	.244	2	.122	6.217	.004	.174	12.434	.878
	fearful	.078	2	.039	4.653	.013	.136	9.307	.763
Error	neutral	1.699	59	.029					
	sad	1.878	59	.032					
	happy	1.962	59	.033					
	angry	.969	59	.016					
	disgusted	.584	59	.010					
	contemptful	.888	59	.015					
	surprised	1.157	59	.020					
	fearful	.497	59	.008					
Total	neutral	19.936	62						
	sad	5.938	62						
	happy	14.237	62						
	angry	6.653	62						
	disgusted	1.534	62						
	contemptful	3.674	62						

	surprised	10.057	62
	fearful	1.049	62
	neutral	1.748	61
	sad	2.063	61
	happy	2.137	61
Corrected	angry	1.523	61
Total	disgusted	.585	61
	contemptful	.913	61
	surprised	1.400	61
	fearful	.576	61

a. R Squared = .028 (Adjusted R Squared = -.005)

b. R Squared = .089 (Adjusted R Squared = .059)

c. R Squared = .082 (Adjusted R Squared = .051)

d. R Squared = .364 (Adjusted R Squared = .342)

e. R Squared = .002 (Adjusted R Squared = -.032)

f. R Squared = .028 (Adjusted R Squared = -.005)

g. R Squared = .174 (Adjusted R Squared = .146)

h. R Squared = .136 (Adjusted R Squared = .107)

i. Computed using alpha =

Multiple Comparisons

Tukey HSD

Dependent Variable	(I) groups	(J) groups	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
neutral	.00	1.00	.0475	.05236	.638	-.0784	.1734
		2.00	-.0194	.05301	.929	-.1468	.1081
	1.00	.00	-.0475	.05236	.638	-.1734	.0784
		2.00	-.0669	.05301	.422	-.1944	.0606
	2.00	.00	.0194	.05301	.929	-.1081	.1468
		1.00	.0669	.05301	.422	-.0606	.1944
sad	.00	1.00	.0655	.05506	.464	-.0669	.1978
		2.00	.1342*	.05574	.050	.0002	.2682
	1.00	.00	-.0655	.05506	.464	-.1978	.0669
		2.00	.0688	.05574	.439	-.0653	.2028
	2.00	.00	-.1342*	.05574	.050	-.2682	-.0002
		1.00	-.0688	.05574	.439	-.2028	.0653
happy	.00	1.00	-.0181	.05628	.945	-.1534	.1172
		2.00	.1034	.05698	.174	-.0336	.2404
	1.00	.00	.0181	.05628	.945	-.1172	.1534
		2.00	.1215	.05698	.092	-.0155	.2585
	2.00	.00	-.1034	.05698	.174	-.2404	.0336
		1.00	-.1215	.05698	.092	-.2585	.0155
angry	.00	1.00	.1707*	.03955	.000	.0756	.2657
		2.00	.2208*	.04004	.000	.1245	.3170
	1.00	.00	-.1707*	.03955	.000	-.2657	-.0756
		2.00	.0501	.04004	.428	-.0462	.1464
	2.00	.00	-.2208*	.04004	.000	-.3170	-.1245
		1.00	-.0501	.04004	.428	-.1464	.0462
disgusted	.00	1.00	-.0095	.03070	.948	-.0833	.0643
		2.00	-.0093	.03109	.952	-.0840	.0655
	1.00	.00	.0095	.03070	.948	-.0643	.0833
		2.00	.0003	.03109	1.000	-.0745	.0750
	2.00	.00	.0093	.03109	.952	-.0655	.0840
		1.00	-.0003	.03109	1.000	-.0750	.0745
contemptful	.00	1.00	-.0477	.03786	.424	-.1387	.0434
		2.00	-.0138	.03833	.931	-.1060	.0783
	1.00	.00	.0477	.03786	.424	-.0434	.1387
		2.00	.0338	.03833	.653	-.0583	.1260
	2.00	.00	.0138	.03833	.931	-.0783	.1060
		1.00	-.0338	.03833	.653	-.1260	.0583

surprised	.00	1.00	.0160	.04321	.928	-.0879	.1198
		2.00	.1414*	.04375	.006	.0362	.2465
	1.00	.00	-.0160	.04321	.928	-.1198	.0879
		2.00	.1254*	.04375	.016	.0202	.2306
	2.00	.00	-.1414*	.04375	.006	-.2465	-.0362
		1.00	-.1254*	.04375	.016	-.2306	-.0202
fearful	.00	1.00	-.0595	.02834	.098	-.1277	.0086
		2.00	.0254	.02869	.651	-.0435	.0944
	1.00	.00	.0595	.02834	.098	-.0086	.1277
		2.00	.0850*	.02869	.012	.0160	.1539
	2.00	.00	-.0254	.02869	.651	-.0944	.0435
		1.00	-.0850*	.02869	.012	-.1539	-.0160

Based on observed means.

The error term is Mean Square(Error) = .008.

*. The mean difference is significant at the

Verbal and Non-Verbal Memory

Descriptive Statistics

	groups	Mean	Std. Deviation	N
Target acc	.00	75.95	16.479	21
	1.00	74.29	15.755	21
	2.00	71.50	15.903	20
	Total	73.95	15.892	62
False neg	.00	27.90	5.924	21
	1.00	25.71	4.766	21
	2.00	21.85	5.797	20
	Total	25.21	5.976	62
digitsrecalled	.00	7.3730	1.24041	21
	1.00	6.8492	1.05133	21
	2.00	6.0833	1.69494	20
	Total	6.7796	1.42951	62

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[d]
Intercept	Pillai's Trace	.987	1395.505[b]	3.000	57.000	.000	.987	4186.515	1.000
	Wilks' Lambda	.013	1395.505[b]	3.000	57.000	.000	.987	4186.515	1.000
	Hotelling's Trace	73.448	1395.505[b]	3.000	57.000	.000	.987	4186.515	1.000
	Roy's Largest Root	73.448	1395.505[b]	3.000	57.000	.000	.987	4186.515	1.000
groups	Pillai's Trace	.277	3.112	6.000	116.000	.007	.139	18.669	.905
	Wilks' Lambda	.723	3.348[b]	6.000	114.000	.004	.150	20.088	.927
	Hotelling's Trace	.383	3.578	6.000	112.000	.003	.161	21.468	.944
	Roy's Largest Root	.383	7.406[c]	3.000	58.000	.000	.277	22.218	.979

a. Design: Intercept + groups

b. Exact statistic

c. The statistic is an upper bound on F that yields a lower bound on the significance level.

d. Computed using alpha =

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[d]
Corrected Model	Target acc	206.617[a]	2	103.308	.401	.671	.013	.802	.112
	False neg	383.629[b]	2	191.814	6.306	.003	.176	12.612	.883
	digitsrecalled	17.192[c]	2	8.596	4.720	.013	.138	9.439	.769
Intercept	Target acc	338532.276	1	338532.276	1314.019	.000	.957	1314.019	1.000
	False neg	39215.449	1	39215.449	1289.231	.000	.956	1289.231	1.000
	digitsrecalled	2838.894	1	2838.894	1558.647	.000	.964	1558.647	1.000
groups	Target acc	206.617	2	103.308	.401	.671	.013	.802	.112
	False neg	383.629	2	191.814	6.306	.003	.176	12.612	.883
	digitsrecalled	17.192	2	8.596	4.720	.013	.138	9.439	.769
Error	Target acc	15200.238	59	257.631					
	False neg	1794.645	59	30.418					
	digitsrecalled	107.462	59	1.821					
Total	Target acc	354475.000	62						
	False neg	41581.000	62						
	digitsrecalled	2974.333	62						
Corrected Total	Target acc	15406.855	61						
	False neg	2178.274	61						
	digitsrecalled	124.654	61						

a. R Squared = .013 (Adjusted R Squared = -.020)

b. R Squared = .176 (Adjusted R Squared = .148)

c. R Squared = .138 (Adjusted R Squared = .109)

d. Computed using alpha =

Multiple Comparisons

Tukey HSD

Dependent Variable	(I) groups	(J) groups	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Target acc	.00	1.00	1.67	4.953	.940	-10.24	13.58
		2.00	4.45	5.015	.650	-7.60	16.51
	1.00	.00	-1.67	4.953	.940	-13.58	10.24
		2.00	2.79	5.015	.844	-9.27	14.84
	2.00	.00	-4.45	5.015	.650	-16.51	7.60
		1.00	-2.79	5.015	.844	-14.84	9.27
False neg	.00	1.00	2.19	1.702	.408	-1.90	6.28
		2.00	6.05*	1.723	.002	1.91	10.20
	1.00	.00	-2.19	1.702	.408	-6.28	1.90
		2.00	3.86	1.723	.072	-.28	8.01
	2.00	.00	-6.05*	1.723	.002	-10.20	-1.91
		1.00	-3.86	1.723	.072	-8.01	.28
digitsrecalled	.00	1.00	.5238	.41649	.425	-.4775	1.5252
		2.00	1.2897*	.42167	.009	.2759	2.3035
	1.00	.00	-.5238	.41649	.425	-1.5252	.4775
		2.00	.7659	.42167	.173	-.2479	1.7797
	2.00	.00	-1.2897*	.42167	.009	-2.3035	-.2759
		1.00	-.7659	.42167	.173	-1.7797	.2479

Based on observed means.

The error term is Mean Square(Error) = 1.821.

*. The mean difference is significant at the

Latency Memory for Faces (Non-verbal memory)

Descriptive Statistics

Dependent Variable: Average Latency

groups	Mean	Std. Deviation	N
.00	1217.03	343.001	21
1.00	1912.88	1013.216	21
2.00	2165.12	680.587	20
Total	1758.56	826.312	62

Tests of Between-Subjects Effects

Dependent Variable: Average Latency

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[b]
Corrected Model	9964395.123[a]	2	4982197.562	9.277	.000	.239	18.554	.972
Intercept	193044069.583	1	193044069.583	359.453	.000	.859	359.453	1.000
groups	9964395.123	2	4982197.562	9.277	.000	.239	18.554	.972
Error	31685890.046	59	537048.984					
Total	233386669.329	62						
Corrected Total	41650285.170	61						

a. R Squared = .239 (Adjusted R Squared = .213)

b. Computed using alpha =

Multiple Comparisons

Dependent Variable: Average Latency

Tukey HSD

(I) groups	(J) groups	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
.00	1.00	-695.85*	226.158	.009	-1239.59	-152.11
	2.00	-948.10*	228.968	.000	-1498.59	-397.60
1.00	.00	695.85*	226.158	.009	152.11	1239.59
	2.00	-252.24	228.968	.517	-802.74	298.25
2.00	.00	948.10*	228.968	.000	397.60	1498.59
	1.00	252.24	228.968	.517	-298.25	802.74

Based on observed means.

The error term is Mean Square(Error) = 537048.984.

*. The mean difference is significant at the

Latency for Span (Verbal-Memory)

Descriptive Statistics

Dependent Variable: latency

groups	Mean	Std. Deviation	N
.00	7.0336	.95395	21
1.00	7.3212	.97946	21
2.00	7.5587	1.05826	20
Total	7.3004	1.00412	62

Tests of Between-Subjects Effects

Dependent Variable: latency

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[b]
Corrected Model	2.838[a]	2	1.419	1.427	.248	.046	2.855	.294
Intercept	3306.306	1	3306.306	3325.141	.000	.983	3325.141	1.000
groups	2.838	2	1.419	1.427	.248	.046	2.855	.294
Error	58.666	59	.994					
Total	3365.847	62						
Corrected Total	61.504	61						

a. R Squared = .046 (Adjusted R Squared = .014)

b. Computed using alpha =

Multiple Comparisons

Dependent Variable: latency

Tukey HSD

(I) groups	(J) groups	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
.00	1.00	-.2876	.30773	.621	-1.0275	.4522
	2.00	-.5251	.31155	.219	-1.2742	.2239
1.00	.00	.2876	.30773	.621	-.4522	1.0275
	2.00	-.2375	.31155	.727	-.9865	.5116
2.00	.00	.5251	.31155	.219	-.2239	1.2742
	1.00	.2375	.31155	.727	-.5116	.9865

Based on observed means.

The error term is Mean Square(Error) = .994.

Study 3

Emotion Processing
Accuracy

Descriptive Statistics

	group	prime	Mean	Std. Deviation	N
neg_sad	.00	Negative	.1345	.06609	11
		Positive	.1873	.10208	15
		Total	.1650	.09105	26
	1.00	Negative	.1929	.09961	17
		Positive	.2229	.11658	7
		Total	.2017	.10315	24
	2.00	Negative	.1815	.09433	13
		Positive	.1730	.07227	10
		Total	.1778	.08372	23
	Total	Negative	.1737	.09126	41
		Positive	.1906	.09588	32
		Total	.1811	.09304	73
pos_happy	.00	Negative	.0827	.09890	11
		Positive	.0587	.06968	15
		Total	.0688	.08233	26
	1.00	Negative	.0959	.10857	17
		Positive	.0771	.08261	7
		Total	.0904	.10028	24
	2.00	Negative	.1162	.09260	13
		Positive	.0450	.04696	10
		Total	.0852	.08295	23
	Total	Negative	.0988	.09953	41
		Positive	.0584	.06551	32
		Total	.0811	.08807	73

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[d]
Intercept	Pillai's Trace	.794	127.276[b]	2.000	66.000	.000	.794	254.551	1.000
	Wilks' Lambda	.206	127.276[b]	2.000	66.000	.000	.794	254.551	1.000
	Hotelling's Trace	3.857	127.276[b]	2.000	66.000	.000	.794	254.551	1.000
	Roy's Largest Root	3.857	127.276[b]	2.000	66.000	.000	.794	254.551	1.000
group	Pillai's Trace	.044	.754	4.000	134.000	.557	.022	3.014	.237
	Wilks' Lambda	.956	.750[b]	4.000	132.000	.559	.022	3.001	.236
	Hotelling's Trace	.046	.747	4.000	130.000	.562	.022	2.987	.235
	Roy's Largest Root	.045	1.515[c]	2.000	67.000	.227	.043	3.029	.312
prime	Pillai's Trace	.121	4.559[b]	2.000	66.000	.014	.121	9.119	.756
	Wilks' Lambda	.879	4.559[b]	2.000	66.000	.014	.121	9.119	.756
	Hotelling's Trace	.138	4.559[b]	2.000	66.000	.014	.121	9.119	.756
	Roy's Largest Root	.138	4.559[b]	2.000	66.000	.014	.121	9.119	.756
group * prime	Pillai's Trace	.027	.452	4.000	134.000	.770	.013	1.810	.154
	Wilks' Lambda	.973	.447[b]	4.000	132.000	.774	.013	1.788	.153
	Hotelling's Trace	.027	.442	4.000	130.000	.778	.013	1.767	.151
	Roy's Largest Root	.023	.767[c]	2.000	67.000	.469	.022	1.533	.175

a. Design: Intercept + group + prime + group * prime

b. Exact statistic

c. The statistic is an upper bound on F that yields a lower bound on the significance level.

d. Computed using alpha =

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[c]
Corrected Model	neg_sad	.040[a]	5	.008	.911	.479	.064	4.554	.306
	pos_happy	.040[b]	5	.008	1.045	.399	.072	5.226	.350
Intercept	neg_sad	2.225	1	2.225	255.409	.000	.792	255.409	1.000
	pos_happy	.422	1	.422	54.548	.000	.449	54.548	1.000
group	neg_sad	.025	2	.012	1.425	.248	.041	2.850	.295
	pos_happy	.003	2	.001	.189	.829	.006	.377	.078
prime	neg_sad	.010	1	.010	1.178	.282	.017	1.178	.188
	pos_happy	.024	1	.024	3.132	.081	.045	3.132	.415
group * prime	neg_sad	.011	2	.006	.653	.524	.019	1.305	.155
	pos_happy	.009	2	.005	.600	.552	.018	1.201	.146
Error	neg_sad	.584	67	.009					
	pos_happy	.518	67	.008					
Total	neg_sad	3.017	73						
	pos_happy	1.039	73						
Corrected Total	neg_sad	.623	72						
	pos_happy	.559	72						

a. R Squared = .064 (Adjusted R Squared = -.006)

b. R Squared = .072 (Adjusted R Squared = .003)

c. Computed using alpha =

Emotion Processing
Latency

Between-Subjects Factors

		Value Label	N
group	.00		26
	1.00		24
	2.00		23
prime	.00	Negative	41
	1.00	Positive	32

Descriptive Statistics

	group	prime	Mean	Std. Deviation	N
latsad	.00	Negative	3763.8209	827.77583	11
		Positive	3935.5747	1028.71056	15
		Total	3862.9096	934.98175	26
	1.00	Negative	4013.0371	856.67610	17
		Positive	4556.6071	1397.07763	7
		Total	4171.5783	1040.86689	24
	2.00	Negative	4857.3885	1078.06702	13
		Positive	4504.2890	1588.72144	10
		Total	4703.8670	1303.27861	23
	Total	Negative	4213.8954	1010.42495	41
		Positive	4249.1487	1295.52983	32
		Total	4229.3489	1135.84895	73
lathappy	.00	Negative	3334.8036	493.66541	11
		Positive	3426.3373	709.55413	15
		Total	3387.6115	617.69782	26
	1.00	Negative	4090.2318	933.06621	17
		Positive	4084.2614	1344.34707	7
		Total	4088.4904	1037.84040	24
	2.00	Negative	4115.2992	717.89377	13
		Positive	3929.6500	1519.50845	10
		Total	4034.5822	1111.08908	23
	Total	Negative	3895.5041	825.86619	41
		Positive	3727.5434	1154.68733	32
		Total	3821.8775	979.80729	73

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[d]
Intercept	Pillai's Trace	.948	595.631[b]	2.000	66.000	.000	.948	1191.262	1.000
	Wilks' Lambda	.052	595.631[b]	2.000	66.000	.000	.948	1191.262	1.000
	Hotelling's Trace	18.049	595.631[b]	2.000	66.000	.000	.948	1191.262	1.000
	Roy's Largest Root	18.049	595.631[b]	2.000	66.000	.000	.948	1191.262	1.000
group	Pillai's Trace	.160	2.913	4.000	134.000	.024	.080	11.654	.773
	Wilks' Lambda	.846	2.886[b]	4.000	132.000	.025	.080	11.543	.768
	Hotelling's Trace	.176	2.858	4.000	130.000	.026	.081	11.431	.763
	Roy's Largest Root	.120	4.028[c]	2.000	67.000	.022	.107	8.056	.700
prime	Pillai's Trace	.010	.325[b]	2.000	66.000	.724	.010	.650	.100
	Wilks' Lambda	.990	.325[b]	2.000	66.000	.724	.010	.650	.100
	Hotelling's Trace	.010	.325[b]	2.000	66.000	.724	.010	.650	.100
	Roy's Largest Root	.010	.325[b]	2.000	66.000	.724	.010	.650	.100
group * prime	Pillai's Trace	.040	.692	4.000	134.000	.599	.020	2.767	.220
	Wilks' Lambda	.960	.687[b]	4.000	132.000	.602	.020	2.747	.218
	Hotelling's Trace	.042	.682	4.000	130.000	.606	.021	2.727	.217
	Roy's Largest Root	.039	1.316[c]	2.000	67.000	.275	.038	2.632	.275

a. Design: Intercept + group + prime + group * prime

b. Exact statistic

c. The statistic is an upper bound on F that yields a lower bound on the significance level.

d. Computed using alpha =

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[c]
Corrected Model	latsad	11107117.000[a]	5	2221423.400	1.820	.121	.120	9.099	.588
	lathappy	7897987.437[b]	5	1579597.487	1.729	.140	.114	8.643	.562
Intercept	latsad	1225212187.136	1	1225212187.136	1003.733	.000	.937	1003.733	1.000
	lathappy	984944792.650	1	984944792.650	1077.873	.000	.941	1077.873	1.000
group	latsad	8287325.677	2	4143662.839	3.395	.039	.092	6.789	.620
	lathappy	7221072.632	2	3610536.316	3.951	.024	.106	7.902	.691
prime	latsad	244706.297	1	244706.297	.200	.656	.003	.200	.073
	lathappy	18682.514	1	18682.514	.020	.887	.000	.020	.052
group * prime	latsad	2168116.034	2	1084058.017	.888	.416	.026	1.776	.197
	lathappy	233525.268	2	116762.634	.128	.880	.004	.256	.069
Error	latsad	81783886.689	67	1220655.025					
	lathappy	61223620.123	67	913785.375					
Total	latsad	1398670630.837	73						
	lathappy	1135414203.295	73						
Corrected Total	latsad	92891003.690	72						
	lathappy	69121607.560	72						

a. R Squared = .120 (Adjusted R Squared = .054)

b. R Squared = .114 (Adjusted R Squared = .048)

c. Computed using alpha =

Multiple Comparisons

Dependent Variable: latsad

Tukey HSD

(I) group	(J) group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
.00	1.00	-308.66872	310.34667	.583	-1051.8129	434.4754
	2.00	-840.95734*	313.83533	.025	-1592.4553	-89.4594
1.00	.00	308.66872	310.34667	.583	-434.4754	1051.8129
	2.00	-532.28862	319.91439	.226	-1298.3433	233.7660
2.00	.00	840.95734*	313.83533	.025	89.4594	1592.4553
	1.00	532.28862	319.91439	.226	-233.7660	1298.3433

*. The mean difference is significant at the 0.05 level.

Multiple Comparisons

Dependent Variable: lathappy

Tukey HSD

(I) group	(J) group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
.00	1.00	-700.87888*	265.26598	.027	-1336.0745	-65.6832
	2.00	-646.97064*	268.24788	.048	-1289.3066	-4.6346
1.00	.00	700.87888*	265.26598	.027	65.6832	1336.0745
	2.00	53.90824	273.44390	.979	-600.8700	708.6864
2.00	.00	646.97064*	268.24788	.048	4.6346	1289.3066
	1.00	-53.90824	273.44390	.979	-708.6864	600.8700

*. The mean difference is significant at the 0.05 level.

Visual Processing

Accuracy

Descriptive Statistics

	group	Mean	Std. Deviation	N
famous faces	.00	3.92	.272	26
	1.00	3.58	.830	24
	2.00	3.30	1.185	23
	Total	3.62	.860	73
dist2	.00	3.96	.196	26
	1.00	3.71	.690	24
	2.00	3.74	.619	23
	Total	3.81	.544	73
dist3	.00	2.88	.711	26
	1.00	2.21	1.021	24
	2.00	1.87	1.014	23
	Total	2.34	1.003	73
dist4	.00	2.69	1.158	26
	1.00	1.83	1.090	24
	2.00	1.26	1.214	23
	Total	1.96	1.285	73
dist5	.00	3.85	.368	26
	1.00	3.83	.381	24
	2.00	3.65	.647	23
	Total	3.78	.479	73
dist6	.00	3.04	1.038	26
	1.00	3.00	1.251	24
	2.00	2.48	1.163	23
	Total	2.85	1.163	73
non-famous	.00	3.92	.272	26
	1.00	3.67	.761	24
	2.00	3.65	.832	23
	Total	3.75	.662	73
dist2nf	.00	3.96	.196	26
	1.00	3.92	.282	24
	2.00	3.78	.422	23
	Total	3.89	.315	73
dist3nf	.00	3.08	.845	26
	1.00	2.38	1.279	24
	2.00	1.43	1.273	23
	Total	2.33	1.313	73
dist4nf	.00	2.69	.970	26

	1.00	2.21	1.103	24
	2.00	1.48	1.123	23
	Total	2.15	1.163	73
dist5nf	.00	3.92	.272	26
	1.00	3.96	.204	24
	2.00	3.74	.541	23
	Total	3.88	.371	73
dist6nf	.00	3.31	.736	26
	1.00	3.17	1.007	24
	2.00	2.96	1.022	23
	Total	3.15	.923	73

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[d]
fame	Pillai's Trace	.109	8.568[b]	1.000	70.000	.005	.109	8.568	.823
	Wilks' Lambda	.891	8.568[b]	1.000	70.000	.005	.109	8.568	.823
	Hotelling's Trace	.122	8.568[b]	1.000	70.000	.005	.109	8.568	.823
	Roy's Largest Root	.122	8.568[b]	1.000	70.000	.005	.109	8.568	.823
fame * group	Pillai's Trace	.011	.403[b]	2.000	70.000	.670	.011	.807	.113
	Wilks' Lambda	.989	.403[b]	2.000	70.000	.670	.011	.807	.113
	Hotelling's Trace	.012	.403[b]	2.000	70.000	.670	.011	.807	.113
	Roy's Largest Root	.012	.403[b]	2.000	70.000	.670	.011	.807	.113
distortion	Pillai's Trace	.886	102.707[b]	5.000	66.000	.000	.886	513.533	1.000
	Wilks' Lambda	.114	102.707[b]	5.000	66.000	.000	.886	513.533	1.000
	Hotelling's Trace	7.781	102.707[b]	5.000	66.000	.000	.886	513.533	1.000
	Roy's Largest Root	7.781	102.707[b]	5.000	66.000	.000	.886	513.533	1.000
distortion * group	Pillai's Trace	.350	2.841	10.000	134.000	.003	.175	28.408	.967
	Wilks' Lambda	.659	3.056[b]	10.000	132.000	.002	.188	30.565	.978
	Hotelling's Trace	.503	3.268	10.000	130.000	.001	.201	32.684	.985
	Roy's Largest Root	.473	6.345[c]	5.000	67.000	.000	.321	31.724	.995
fame * distortion	Pillai's Trace	.063	.889[b]	5.000	66.000	.494	.063	4.445	.298
	Wilks' Lambda	.937	.889[b]	5.000	66.000	.494	.063	4.445	.298
	Hotelling's Trace	.067	.889[b]	5.000	66.000	.494	.063	4.445	.298
	Roy's Largest Root	.067	.889[b]	5.000	66.000	.494	.063	4.445	.298
fame * distortion * group	Pillai's Trace	.212	1.587	10.000	134.000	.117	.106	15.866	.754
	Wilks' Lambda	.792	1.630[b]	10.000	132.000	.105	.110	16.304	.768

	Hotelling's Trace	.257	1.672	10.000	130.000	.094	.114	16.724	.780
	Roy's Largest Root	.236	3.165[c]	5.000	67.000	.013	.191	15.823	.855

a. Design: Intercept + group

Within Subjects Design: fame + distortion + fame * distortion

b. Exact statistic

c. The statistic is an upper bound on F that yields a lower bound on the significance level.

d. Computed using alpha =

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
fame	Sphericity Assumed	3.892	1	3.892	8.568	.005	.109	8.568	.823
	Greenhouse-Geisser	3.892	1.000	3.892	8.568	.005	.109	8.568	.823
	Huynh-Feldt	3.892	1.000	3.892	8.568	.005	.109	8.568	.823
	Lower-bound	3.892	1.000	3.892	8.568	.005	.109	8.568	.823
fame * group	Sphericity Assumed	.366	2	.183	.403	.670	.011	.807	.113
	Greenhouse-Geisser	.366	2.000	.183	.403	.670	.011	.807	.113
	Huynh-Feldt	.366	2.000	.183	.403	.670	.011	.807	.113
	Lower-bound	.366	2.000	.183	.403	.670	.011	.807	.113
Error(fame)	Sphericity Assumed	31.793	70	.454					
	Greenhouse-Geisser	31.793	70.000	.454					
	Huynh-Feldt	31.793	70.000	.454					
	Lower-bound	31.793	70.000	.454					
distortion	Sphericity Assumed	466.034	5	93.207	94.164	.000	.574	470.818	1.000
	Greenhouse-Geisser	466.034	2.602	179.114	94.164	.000	.574	245.002	1.000
	Huynh-Feldt	466.034	2.788	167.129	94.164	.000	.574	262.572	1.000
	Lower-bound	466.034	1.000	466.034	94.164	.000	.574	94.164	1.000
distortion * group	Sphericity Assumed	35.730	10	3.573	3.610	.000	.093	36.097	.995
	Greenhouse-Geisser	35.730	5.204	6.866	3.610	.003	.093	18.784	.927
	Huynh-Feldt	35.730	5.577	6.407	3.610	.003	.093	20.131	.940
	Lower-bound	35.730	2.000	17.865	3.610	.032	.093	7.219	.650
Error(distortion)	Sphericity Assumed	346.443	350	.990					
	Greenhouse-Geisser	346.443	182.131	1.902					
	Huynh-Feldt	346.443	195.192	1.775					
	Lower-bound	346.443	70.000	4.949					

fame * distortion	Sphericity Assumed	2.278	5	.456	1.044	.392	.015	5.220	.372
	Greenhouse-Geisser	2.278	3.704	.615	1.044	.382	.015	3.867	.315
	Huynh-Feldt	2.278	4.049	.563	1.044	.385	.015	4.227	.330
	Lower-bound	2.278	1.000	2.278	1.044	.310	.015	1.044	.172
fame * distortion * group	Sphericity Assumed	5.196	10	.520	1.191	.296	.033	11.908	.621
	Greenhouse-Geisser	5.196	7.409	.701	1.191	.307	.033	8.823	.525
	Huynh-Feldt	5.196	8.098	.642	1.191	.304	.033	9.643	.552
	Lower-bound	5.196	2.000	2.598	1.191	.310	.033	2.382	.253
Error(fame*distortion)	Sphericity Assumed	152.713	350	.436					
	Greenhouse-Geisser	152.713	259.315	.589					
	Huynh-Feldt	152.713	283.428	.539					
	Lower-bound	152.713	70.000	2.182					

a. Computed using alpha =

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intercept	8462.525	1	8462.525	7830.569	.000	.991	7830.569	1.000
group	63.205	2	31.602	29.242	.000	.455	58.485	1.000
Error	75.649	70	1.081					

a. Computed using alpha =

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
normalrightsideup	.00	26	3.9231	.18397	.03608	3.8488	3.9974	3.50	4.00
	1.00	24	3.6250	.75542	.15420	3.3060	3.9440	1.00	4.00
	2.00	23	3.4783	.98256	.20488	3.0534	3.9031	.50	4.00
	Total	73	3.6849	.72412	.08475	3.5160	3.8539	.50	4.00
eyesdistortedrightsideup	.00	26	3.9615	.13587	.02665	3.9067	4.0164	3.50	4.00
	1.00	24	3.8125	.35547	.07256	3.6624	3.9626	2.50	4.00
	2.00	23	3.7609	.36524	.07616	3.6029	3.9188	3.00	4.00
	Total	73	3.8493	.30828	.03608	3.7774	3.9212	2.50	4.00
eyesmouthdistortedrightsideup	.00	26	2.9808	.68528	.13440	2.7040	3.2576	1.00	4.00
	1.00	24	2.2917	.90790	.18532	1.9083	2.6750	.00	4.00
	2.00	23	1.6522	.92238	.19233	1.2533	2.0510	.00	4.00
	Total	73	2.3356	.99322	.11625	2.1039	2.5674	.00	4.00
normalupsidedown	.00	26	2.6923	.89529	.17558	2.3307	3.0539	.50	4.00
	1.00	24	2.0208	.93807	.19148	1.6247	2.4169	.00	4.00
	2.00	23	1.3696	.94409	.19686	.9613	1.7778	.00	3.50
	Total	73	2.0548	1.06250	.12436	1.8069	2.3027	.00	4.00
eyesdupsidedown	.00	26	3.8846	.21483	.04213	3.7978	3.9714	3.50	4.00
	1.00	24	3.8958	.25449	.05195	3.7884	4.0033	3.00	4.00
	2.00	23	3.6957	.47047	.09810	3.4922	3.8991	2.00	4.00
	Total	73	3.8288	.33561	.03928	3.7505	3.9071	2.00	4.00
eyesmouthdupsidedown	.00	26	3.1731	.69199	.13571	2.8936	3.4526	1.00	4.00
	1.00	24	3.0833	.94024	.19193	2.6863	3.4804	.00	4.00
	2.00	23	2.7174	.96326	.20085	2.3008	3.1339	.00	4.00
	Total	73	3.0000	.87797	.10276	2.7952	3.2048	.00	4.00

Visual Processing
Latency

Descriptive Statistics

	group	Mean	Std. Deviation	N
rtdist1	.00	1438.39215	695.094675	26
	1.00	1817.13317	1043.560746	24
	2.00	2611.31417	2064.910211	23
	Total	1932.46052	1434.671949	73
rtdist2	.00	1267.32373	496.713259	26
	1.00	1549.16671	761.988885	24
	2.00	1839.67030	966.893574	23
	Total	1540.31281	782.540177	73
rtdist3	.00	2133.64746	1445.506565	26
	1.00	2771.29933	1779.612290	24
	2.00	3019.32317	1590.770034	23
	Total	2622.33495	1629.235235	73
rtdist4	.00	1714.75035	687.226062	26
	1.00	2488.49387	1868.182026	24
	2.00	2024.46548	990.992070	23
	Total	2066.71326	1297.520457	73
rtdist5	.00	1731.71154	950.642966	26
	1.00	2103.36808	1075.877183	24
	2.00	2521.44570	1635.322360	23
	Total	2102.72034	1267.441762	73
rtdist6	.00	1985.88923	725.854484	26
	1.00	2342.92167	1404.456739	24
	2.00	3204.15374	2272.566144	23
	Total	2487.10652	1628.801432	73
rtdist1nf	.00	1177.81731	530.877300	26
	1.00	1647.68400	1091.343978	24
	2.00	1923.37317	1076.499509	23
	Total	1567.19519	964.289766	73
rtdist2nf	.00	1221.92308	468.991992	26
	1.00	1554.88892	758.545829	24
	2.00	1971.59057	1320.035517	23
	Total	1567.58790	942.309421	73
rtdist3nf	.00	1766.54488	871.007660	26
	1.00	2338.06442	1054.988192	24
	2.00	2800.66274	1515.559820	23
	Total	2280.25967	1226.264361	73
rtdist4nf	.00	2105.10577	1629.105444	26

	1.00	2960.45558	1378.816315	24
	2.00	2581.83913	1078.288872	23
	Total	2536.52033	1418.405220	73
rt5distnf	.00	1412.16346	674.503430	26
	1.00	2077.69096	980.876076	24
	2.00	2046.13404	1317.864793	23
	Total	1830.71118	1046.140692	73
rtdist6nf	.00	2232.85896	1615.886689	26
	1.00	2515.60042	872.106792	24
	2.00	2443.65191	1276.218159	23
	Total	2392.22927	1289.320248	73

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[d]
fame	Pillai's Trace	.033	2.352[b]	1.000	70.000	.130	.033	2.352	.328
	Wilks' Lambda	.967	2.352[b]	1.000	70.000	.130	.033	2.352	.328
	Hotelling's Trace	.034	2.352[b]	1.000	70.000	.130	.033	2.352	.328
	Roy's Largest Root	.034	2.352[b]	1.000	70.000	.130	.033	2.352	.328
fame * group	Pillai's Trace	.035	1.255[b]	2.000	70.000	.291	.035	2.510	.264
	Wilks' Lambda	.965	1.255[b]	2.000	70.000	.291	.035	2.510	.264
	Hotelling's Trace	.036	1.255[b]	2.000	70.000	.291	.035	2.510	.264
	Roy's Largest Root	.036	1.255[b]	2.000	70.000	.291	.035	2.510	.264
distortion	Pillai's Trace	.535	15.183[b]	5.000	66.000	.000	.535	75.917	1.000
	Wilks' Lambda	.465	15.183[b]	5.000	66.000	.000	.535	75.917	1.000
	Hotelling's Trace	1.150	15.183[b]	5.000	66.000	.000	.535	75.917	1.000
	Roy's Largest Root	1.150	15.183[b]	5.000	66.000	.000	.535	75.917	1.000
distortion * group	Pillai's Trace	.192	1.424	10.000	134.000	.176	.096	14.242	.697
	Wilks' Lambda	.815	1.420[b]	10.000	132.000	.178	.097	14.204	.695
	Hotelling's Trace	.218	1.416	10.000	130.000	.180	.098	14.162	.692
	Roy's Largest Root	.163	2.186[c]	5.000	67.000	.066	.140	10.932	.681
fame * distortion	Pillai's Trace	.179	2.885[b]	5.000	66.000	.020	.179	14.423	.815
	Wilks' Lambda	.821	2.885[b]	5.000	66.000	.020	.179	14.423	.815
	Hotelling's Trace	.219	2.885[b]	5.000	66.000	.020	.179	14.423	.815
	Roy's Largest Root	.219	2.885[b]	5.000	66.000	.020	.179	14.423	.815
fame * distortion * group	Pillai's Trace	.159	1.158	10.000	134.000	.325	.080	11.582	.585
	Wilks' Lambda	.844	1.171[b]	10.000	132.000	.316	.081	11.708	.590
	Hotelling's Trace	.182	1.182	10.000	130.000	.308	.083	11.825	.595
	Roy's Largest Root	.161	2.160[c]	5.000	67.000	.069	.139	10.801	.675

a. Design: Intercept + group

Within Subjects Design: fame + distortion + fame * distortion

b. Exact statistic

c. The statistic is an upper bound on F that yields a lower bound on the significance level.

d. Computed using alpha =

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
fame	Sphericity Assumed	2151517.942	1	2151517.942	2.352	.130	.033	2.352	.328
	Greenhouse-Geisser	2151517.942	1.000	2151517.942	2.352	.130	.033	2.352	.328
	Huynh-Feldt	2151517.942	1.000	2151517.942	2.352	.130	.033	2.352	.328
	Lower-bound	2151517.942	1.000	2151517.942	2.352	.130	.033	2.352	.328
fame * group	Sphericity Assumed	2295308.347	2	1147654.173	1.255	.291	.035	2.510	.264
	Greenhouse-Geisser	2295308.347	2.000	1147654.173	1.255	.291	.035	2.510	.264
	Huynh-Feldt	2295308.347	2.000	1147654.173	1.255	.291	.035	2.510	.264
	Lower-bound	2295308.347	2.000	1147654.173	1.255	.291	.035	2.510	.264
Error(fame)	Sphericity Assumed	64023673.089	70	914623.901					
	Greenhouse-Geisser	64023673.089	70.000	914623.901					
	Huynh-Feldt	64023673.089	70.000	914623.901					
	Lower-bound	64023673.089	70.000	914623.901					
distortion	Sphericity Assumed	104162857.130	5	20832571.426	19.192	.000	.215	95.960	1.000
	Greenhouse-Geisser	104162857.130	4.306	24190849.336	19.192	.000	.215	82.639	1.000
	Huynh-Feldt	104162857.130	4.754	21909219.438	19.192	.000	.215	91.245	1.000
	Lower-bound	104162857.130	1.000	104162857.130	19.192	.000	.215	19.192	.991
distortion * group	Sphericity Assumed	15560459.185	10	1556045.919	1.434	.164	.039	14.335	.722
	Greenhouse-Geisser	15560459.185	8.612	1806885.555	1.434	.176	.039	12.345	.671

	Huynh-Feldt	15560459.185	9.509	1636463.919	1.434	.168	.039	13.631	.705
	Lower-bound	15560459.185	2.000	7780229.593	1.434	.245	.039	2.867	.297
Error(distortion)	Sphericity Assumed	379916843.269	350	1085476.695					
	Greenhouse-Geisser	379916843.269	301.411	1260459.050					
	Huynh-Feldt	379916843.269	332.801	1141575.210					
	Lower-bound	379916843.269	70.000	5427383.475					
fame * distortion	Sphericity Assumed	18485326.224	5	3697065.245	4.486	.001	.060	22.430	.970
	Greenhouse-Geisser	18485326.224	3.954	4675587.539	4.486	.002	.060	17.736	.936
	Huynh-Feldt	18485326.224	4.340	4259735.267	4.486	.001	.060	19.467	.952
	Lower-bound	18485326.224	1.000	18485326.224	4.486	.038	.060	4.486	.551
fame * distortion * group	Sphericity Assumed	8864368.822	10	886436.882	1.076	.380	.030	10.756	.567
	Greenhouse-Geisser	8864368.822	7.907	1121054.936	1.076	.380	.030	8.505	.495
	Huynh-Feldt	8864368.822	8.679	1021346.987	1.076	.380	.030	9.335	.522
	Lower-bound	8864368.822	2.000	4432184.411	1.076	.347	.030	2.151	.231
Error(fame*distortion)	Sphericity Assumed	288449182.438	350	824140.521					
	Greenhouse-Geisser	288449182.438	276.751	1042270.259					
	Huynh-Feldt	288449182.438	303.768	949569.513					
	Lower-bound	288449182.438	70.000	4120702.606					

a. Computed using alpha =

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intercept	3826994506.546	1	3826994506.546	485.884	.000	.874	485.884	1.000
group	83333956.853	2	41666978.427	5.290	.007	.131	10.580	.821
Error	551345077.189	70	7876358.246					

a. Computed using alpha =

Multiple Comparisons

Measure: MEASURE_1

Tukey HSD

(I) group	(J) group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
.00	1.00	-498.21993	229.332083	.083	-1047.36968	50.92981
	2.00	-733.29135*	231.910043	.006	-1288.61418	-177.96852
1.00	.00	498.21993	229.332083	.083	-50.92981	1047.36968
	2.00	-235.07142	236.402191	.583	-801.15097	331.00813
2.00	.00	733.29135*	231.910043	.006	177.96852	1288.61418
	1.00	235.07142	236.402191	.583	-331.00813	801.15097

Based on observed means.

The error term is Mean Square(Error) = 656363.187.

*. The mean difference is significant at the

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	rtdist1	1932.46052	73	1434.671949	167.915651
	rtdist1nf	1567.19519	73	964.289766	112.861580
Pair 2	rtdist2	1540.31281	73	782.540177	91.589400
	rtdist2nf	1567.58790	73	942.309421	110.288976
Pair 3	rtdist3	2622.33495	73	1629.235235	190.687561
	rtdist3nf	2280.25967	73	1226.264361	143.523388
Pair 4	rtdist4	2066.71326	73	1297.520457	151.863283
	rtdist4nf	2536.52033	73	1418.405220	166.011774
Pair 5	rtdist5	2102.72034	73	1267.441762	148.342838
	rt5distnf	1830.71118	73	1046.140692	122.441507
Pair 6	rtdist6	2487.10652	73	1628.801432	190.636788
	rtdist6nf	2392.22927	73	1289.320248	150.903521

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	rtdist1 - rtdist1nf	365.265329	1204.981343	141.032399	84.122380	646.408277	2.590	72	.012
Pair 2	rtdist2 - rtdist2nf	-27.275096	707.902488	82.853719	-192.440967	137.890775	-.329	72	.743
Pair 3	rtdist3 - rtdist3nf	342.075274	1507.238628	176.408938	-9.589517	693.740065	1.939	72	.056
Pair 4	rtdist4 - rtdist4nf	-469.807068	1700.742416	199.056843	-866.619634	-72.994503	-2.360	72	.021
Pair 5	rtdist5 - rt5distnf	272.009164	924.609902	108.217404	56.281713	487.736616	2.514	72	.014
Pair 6	rtdist6 - rtdist6nf	94.877247	1458.972652	170.759833	-245.526259	435.280752	.556	72	.580

Span
Mean Span

Descriptive Statistics

Dependent Variable: span

group	Mean	Std. Deviation	N
.00	7.3231	.94501	26
1.00	6.5833	1.33177	24
2.00	6.0870	1.21330	23
Total	6.6904	1.26141	73

Tests of Between-Subjects Effects

Dependent Variable: span

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[b]
Corrected Model	19.058[a]	2	9.529	6.984	.002	.166	13.968	.916
Intercept	3233.930	1	3233.930	2370.282	.000	.971	2370.282	1.000
group	19.058	2	9.529	6.984	.002	.166	13.968	.916
Error	95.506	70	1.364					
Total	3382.160	73						
Corrected Total	114.563	72						

a. R Squared = .166 (Adjusted R Squared = .143)

b. Computed using alpha =

Multiple Comparisons

Dependent Variable: span

Tukey HSD

(I) group	(J) group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
.00	1.00	.7397	.33064	.072	-.0520	1.5315
	2.00	1.2361*	.33436	.001	.4355	2.0368
1.00	.00	-.7397	.33064	.072	-1.5315	.0520
	2.00	.4964	.34084	.318	-.3198	1.3125
2.00	.00	-1.2361*	.33436	.001	-2.0368	-.4355
	1.00	-.4964	.34084	.318	-1.3125	.3198

Based on observed means.

The error term is Mean Square(Error) = 1.364.

*. The mean difference is significant at the

Span
Mean Latency

Descriptive Statistics

Dependent Variable: latency

group	Mean	Std. Deviation	N
.00	6.2297	1.28841	26
1.00	6.5441	1.29657	24
2.00	6.7495	1.27242	23
Total	6.4968	1.28648	73

Tests of Between-Subjects Effects

Dependent Variable: latency

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[b]
Corrected Model	3.378[a]	2	1.689	1.021	.365	.028	2.042	.221
Intercept	3083.651	1	3083.651	1864.284	.000	.964	1864.284	1.000
group	3.378	2	1.689	1.021	.365	.028	2.042	.221
Error	115.785	70	1.654					
Total	3200.411	73						
Corrected Total	119.163	72						

a. R Squared = .028 (Adjusted R Squared = .001)

b. Computed using alpha =

Emotion Recognition
Accuracy

Descriptive Statistics

	group	Mean	Std. Deviation	N
neutral	.00	.60585	.170847	26
	1.00	.55550	.174928	24
	2.00	.61591	.162288	23
	Total	.59247	.169272	73
sad	.00	.30288	.166482	26
	1.00	.25521	.130213	24
	2.00	.26630	.204023	23
	Total	.27568	.167911	73
happy	.00	.49700	.158480	26
	1.00	.48717	.186367	24
	2.00	.40478	.162463	23
	Total	.46471	.171967	73
angry	.00	.40377	.155758	26
	1.00	.23958	.146011	24
	2.00	.19570	.111341	23
	Total	.28423	.165380	73
disgusted	.00	.13588	.107449	26
	1.00	.15008	.124765	24
	2.00	.11891	.122197	23
	Total	.13521	.117059	73
contemptful	.00	.19550	.168331	26
	1.00	.18404	.109870	24
	2.00	.18113	.145751	23
	Total	.18721	.142218	73
surprised	.00	.38146	.127305	26
	1.00	.38542	.176972	24
	2.00	.32248	.181696	23
	Total	.36418	.162890	73
fearful	.00	.08654	.076423	26
	1.00	.12154	.077761	24
	2.00	.07970	.092299	23
	Total	.09589	.083050	73

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[i]
Corrected Model	neutral	.050[a]	2	.025	.871	.423	.024	1.742	.194
	sad	.031[b]	2	.016	.549	.580	.015	1.097	.137
	happy	.122[c]	2	.061	2.124	.127	.057	4.248	.422
	angry	.600[d]	2	.300	15.324	.000	.305	30.648	.999
	disgusted	.011[e]	2	.006	.410	.665	.012	.820	.114
	contemptful	.003[f]	2	.001	.069	.933	.002	.139	.060
	surprised	.059[g]	2	.029	1.107	.336	.031	2.215	.237
	fearful	.024[h]	2	.012	1.785	.175	.049	3.570	.361
Intercept	neutral		1	25.554	888.646	.000	.927	888.646	1.000
	sad	5.498	1	5.498	192.573	.000	.733	192.573	1.000
	happy	15.607	1	15.607	544.239	.000	.886	544.239	1.000
	angry	5.696	1	5.696	291.100	.000	.806	291.100	1.000
	disgusted	1.326	1	1.326	95.199	.000	.576	95.199	1.000
	contemptful	2.543	1	2.543	122.488	.000	.636	122.488	1.000
	surprised	9.601	1	9.601	362.913	.000	.838	362.913	1.000
	fearful	.670	1	.670	99.256	.000	.586	99.256	1.000
group	neutral	.050	2	.025	.871	.423	.024	1.742	.194
	sad	.031	2	.016	.549	.580	.015	1.097	.137
	happy	.122	2	.061	2.124	.127	.057	4.248	.422
	angry	.600	2	.300	15.324	.000	.305	30.648	.999
	disgusted	.011	2	.006	.410	.665	.012	.820	.114
	contemptful	.003	2	.001	.069	.933	.002	.139	.060
	surprised	.059	2	.029	1.107	.336	.031	2.215	.237
	fearful	.024	2	.012	1.785	.175	.049	3.570	.361
Error	neutral	2.013	70	.029					
	sad	1.999	70	.029					
	happy	2.007	70	.029					
	angry	1.370	70	.020					
	disgusted	.975	70	.014					
	contemptful	1.453	70	.021					
	surprised	1.852	70	.026					
	fearful	.473	70	.007					
Total	neutral	27.687	73						
	sad	7.578	73						
	happy	17.894	73						
	angry	7.867	73						
	disgusted	2.321	73						
	contemptful	4.015	73						
	surprised	11.592	73						

	fearful	1.168	73						
	neutral	2.063	72						
	sad	2.030	72						
	happy	2.129	72						
Corrected	angry	1.969	72						
Total	disgusted	.987	72						
	contemptful	1.456	72						
	surprised	1.910	72						
	fearful	.497	72						

a. R Squared = .024 (Adjusted R Squared = -.004)

b. R Squared = .015 (Adjusted R Squared = -.013)

c. R Squared = .057 (Adjusted R Squared = .030)

d. R Squared = .305 (Adjusted R Squared = .285)

e. R Squared = .012 (Adjusted R Squared = -.017)

f. R Squared = .002 (Adjusted R Squared = -.027)

g. R Squared = .031 (Adjusted R Squared = .003)

h. R Squared = .049 (Adjusted R Squared = .021)

i. Computed using alpha =

Multiple Comparisons

Tukey HSD

Dependent Variable	(I) group	(J) group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
neutral	.00	1.00	.05035	.048002	.549	-.06460	.16529
		2.00	-.01007	.048541	.977	-.12630	.10617
	1.00	.00	-.05035	.048002	.549	-.16529	.06460
		2.00	-.06041	.049482	.445	-.17890	.05807
	2.00	.00	.01007	.048541	.977	-.10617	.12630
		1.00	.06041	.049482	.445	-.05807	.17890
sad	.00	1.00	.04768	.047831	.581	-.06686	.16221
		2.00	.03658	.048369	.731	-.07924	.15240
	1.00	.00	-.04768	.047831	.581	-.16221	.06686
		2.00	-.01110	.049306	.972	-.12916	.10697
	2.00	.00	-.03658	.048369	.731	-.15240	.07924
		1.00	.01110	.049306	.972	-.10697	.12916
happy	.00	1.00	.00983	.047936	.977	-.10495	.12462
		2.00	.09222	.048475	.146	-.02386	.20829
	1.00	.00	-.00983	.047936	.977	-.12462	.10495
		2.00	.08238	.049414	.225	-.03594	.20071
	2.00	.00	-.09222	.048475	.146	-.20829	.02386
		1.00	-.08238	.049414	.225	-.20071	.03594
angry	.00	1.00	.16419*	.039595	.000	.06937	.25900
		2.00	.20807*	.040040	.000	.11220	.30395
	1.00	.00	-.16419*	.039595	.000	-.25900	-.06937
		2.00	.04389	.040815	.532	-.05385	.14162
	2.00	.00	-.20807*	.040040	.000	-.30395	-.11220
		1.00	-.04389	.040815	.532	-.14162	.05385
disgusted	.00	1.00	-.01420	.033410	.905	-.09420	.06580
		2.00	.01697	.033786	.870	-.06393	.09787
	1.00	.00	.01420	.033410	.905	-.06580	.09420
		2.00	.03117	.034440	.639	-.05130	.11364
	2.00	.00	-.01697	.033786	.870	-.09787	.06393
		1.00	-.03117	.034440	.639	-.11364	.05130
contemptful	.00	1.00	.01146	.040788	.957	-.08621	.10913
		2.00	.01437	.041247	.935	-.08440	.11314
	1.00	.00	-.01146	.040788	.957	-.10913	.08621
		2.00	.00291	.042046	.997	-.09777	.10359
	2.00	.00	-.01437	.041247	.935	-.11314	.08440
		1.00	-.00291	.042046	.997	-.10359	.09777
surprised	.00	1.00	-.00396	.046041	.996	-.11420	.10629

		2.00	.05898	.046558	.419	-.05250	.17047
	1.00	.00	.00396	.046041	.996	-.10629	.11420
		2.00	.06294	.047460	.386	-.05071	.17658
	2.00	.00	-.05898	.046558	.419	-.17047	.05250
		1.00	-.06294	.047460	.386	-.17658	.05071
	.00	1.00	-.03500	.023257	.295	-.09069	.02069
		2.00	.00684	.023518	.954	-.04947	.06316
fearful	1.00	.00	.03500	.023257	.295	-.02069	.09069
		2.00	.04185	.023974	.196	-.01556	.09925
	2.00	.00	-.00684	.023518	.954	-.06316	.04947
		1.00	-.04185	.023974	.196	-.09925	.01556

Based on observed means.

The error term is Mean Square(Error) = .007.

*. The mean difference is significant at the

Emotion Recognition
Latency

Descriptive Statistics

	group	Mean	Std. Deviation	N
neutralrt	.00	20821.62	8423.064	26
	1.00	31669.58	13080.700	24
	2.00	29610.43	12051.870	23
	Total	27157.15	12119.364	73
sadrt	.00	16362.88	6312.554	26
	1.00	23103.46	9173.125	24
	2.00	23897.74	9128.466	23
	Total	20952.96	8837.292	73
happyrt	.00	27831.81	8800.304	26
	1.00	38439.33	13816.420	24
	2.00	37605.22	13488.994	23
	Total	34398.51	12952.475	73
angryrt	.00	24846.23	10577.976	26
	1.00	36958.71	10716.414	24
	2.00	38977.35	15104.275	23
	Total	33280.68	13631.285	73
disgustedrt	.00	37596.35	12320.609	26
	1.00	47683.63	14640.305	24
	2.00	47240.48	15586.888	23
	Total	43951.27	14768.031	73
contemptfulrt	.00	28039.27	8998.782	26
	1.00	36986.62	10186.496	24
	2.00	37296.91	13068.668	23
	Total	33897.66	11520.227	73
surprisedrt	.00	25001.46	8526.936	26
	1.00	37075.50	15058.038	24
	2.00	32099.26	8366.373	23
	Total	31207.30	12029.383	73
fearfulrt	.00	23235.00	5081.106	26
	1.00	33295.75	10842.716	24
	2.00	29833.70	11689.440	23
	Total	28621.68	10319.956	73

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[d]
Intercept	Pillai's Trace	.954	162.907[b]	8.000	63.000	.000	.954	1303.255	1.000
	Wilks' Lambda	.046	162.907[b]	8.000	63.000	.000	.954	1303.255	1.000
	Hotelling's Trace	20.687	162.907[b]	8.000	63.000	.000	.954	1303.255	1.000
	Roy's Largest Root	20.687	162.907[b]	8.000	63.000	.000	.954	1303.255	1.000
group	Pillai's Trace	.428	2.176	16.000	128.000	.009	.214	34.822	.971
	Wilks' Lambda	.606	2.241[b]	16.000	126.000	.007	.222	35.851	.975
	Hotelling's Trace	.594	2.303	16.000	124.000	.005	.229	36.845	.978
	Roy's Largest Root	.478	3.820[c]	8.000	64.000	.001	.323	30.562	.980

a. Design: Intercept + group

b. Exact statistic

c. The statistic is an upper bound on F that yields a lower bound on the significance level.

d. Computed using alpha =

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[i]
Corrected Model	neutralrt	1670731223.703[a]	2	835365611.852	6.567	.002	.158	13.134	.898
	sadrt	858229681.830[b]	2	429114840.915	6.304	.003	.153	12.608	.885
	happyrt	1749547498.962[c]	2	874773749.481	5.928	.004	.145	11.856	.864
	angryrt	2920704256.962[d]	2	1460352128.481	9.775	.000	.218	19.550	.979
	disgustedrt	1633177349.272[e]	2	816588674.636	4.063	.021	.104	8.125	.705
	contemptfulrt	1387103405.872[f]	2	693551702.936	5.943	.004	.145	11.887	.865
	surprisedrt	1846080382.474[g]	2	923040191.237	7.537	.001	.177	15.074	.935
	fearfulrt	1312537270.384[h]	2	656268635.192	7.228	.001	.171	14.456	.925
Intercept	neutralrt	54533378727.788	1	54533378727.788	428.695	.000	.860	428.695	1.000
	sadrt	32482175307.933	1	32482175307.933	477.197	.000	.872	477.197	1.000
	happyrt	87295577548.187	1	87295577548.187	591.568	.000	.894	591.568	1.000
	angryrt	82172637787.025	1	82172637787.025	550.031	.000	.887	550.031	1.000
	disgustedrt	142077272182.468	1	142077272182.468	706.870	.000	.910	706.870	1.000
	contemptfulrt	84703957871.198	1	84703957871.198	725.878	.000	.912	725.878	1.000
	surprisedrt	71753211253.577	1	71753211253.577	585.894	.000	.893	585.894	1.000
	fearfulrt	60343262891.618	1	60343262891.618	664.618	.000	.905	664.618	1.000
group	neutralrt	1670731223.703	2	835365611.852	6.567	.002	.158	13.134	.898
	sadrt	858229681.830	2	429114840.915	6.304	.003	.153	12.608	.885
	happyrt	1749547498.962	2	874773749.481	5.928	.004	.145	11.856	.864
	angryrt	2920704256.962	2	1460352128.481	9.775	.000	.218	19.550	.979
	disgustedrt	1633177349.272	2	816588674.636	4.063	.021	.104	8.125	.705
	contemptfulrt	1387103405.872	2	693551702.936	5.943	.004	.145	11.887	.865
	surprisedrt	1846080382.474	2	923040191.237	7.537	.001	.177	15.074	.935
	fearfulrt	1312537270.384	2	656268635.192	7.228	.001	.171	14.456	.925
Error	neutralrt	8904555323.639	70	127207933.195					
	sadrt	4764807245.047	70	68068674.929					
	happyrt	10329648367.285	70	147566405.247					
	angryrt	10457755156.791	70	149396502.240					
	disgustedrt	14069644807.249	70	200994925.818					
	contemptfulrt	8168421654.566	70	116691737.922					
	surprisedrt	8572756142.896	70	122467944.899					
	fearfulrt	6355570275.370	70	90793861.077					
Total	neutralrt	64413577380.000	73						
	sadrt	37671970466.000	73						
	happyrt	98456976829.000	73						
	angryrt	94233550648.000	73						
	disgustedrt	156717979475.000	73						

	contemptfulrt	93436261661.000	73						
	surprisedrt	81513219617.000	73						
	fearfulrt	67469769473.000	73						
	neutralrt	10575286547.342	72						
	sadrt	5623036926.877	72						
	happyrt	12079195866.247	72						
Corrected	angryrt	13378459413.753	72						
Total	disgustedrt	15702822156.521	72						
	contemptfulrt	9555525060.438	72						
	surprisedrt	10418836525.370	72						
	fearfulrt	7668107545.753	72						

a. R Squared = .158 (Adjusted R Squared = .134)

b. R Squared = .153 (Adjusted R Squared = .128)

c. R Squared = .145 (Adjusted R Squared = .120)

d. R Squared = .218 (Adjusted R Squared = .196)

e. R Squared = .104 (Adjusted R Squared = .078)

f. R Squared = .145 (Adjusted R Squared = .121)

g. R Squared = .177 (Adjusted R Squared = .154)

h. R Squared = .171 (Adjusted R Squared = .147)

i. Computed using alpha =

Multiple Comparisons

Tukey HSD

Dependent Variable	(I) group	(J) group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
neutralrt	.00	1.00	-10847.97*	3192.639	.003	-18492.94	-3203.00
		2.00	-8788.82*	3228.528	.022	-16519.73	-1057.91
	1.00	.00	10847.97*	3192.639	.003	3203.00	18492.94
		2.00	2059.15	3291.065	.807	-5821.51	9939.81
	2.00	.00	8788.82*	3228.528	.022	1057.91	16519.73
		1.00	-2059.15	3291.065	.807	-9939.81	5821.51
sadrt	.00	1.00	-6740.57*	2335.427	.014	-12332.90	-1148.25
		2.00	-7534.85*	2361.680	.006	-13190.04	-1879.67
	1.00	.00	6740.57*	2335.427	.014	1148.25	12332.90
		2.00	-794.28	2407.427	.942	-6559.01	4970.45
	2.00	.00	7534.85*	2361.680	.006	1879.67	13190.04
		1.00	794.28	2407.427	.942	-4970.45	6559.01
happyrt	.00	1.00	-10607.53*	3438.638	.008	-18841.56	-2373.50
		2.00	-9773.41*	3477.292	.017	-18100.00	-1446.82
	1.00	.00	10607.53*	3438.638	.008	2373.50	18841.56
		2.00	834.12	3544.648	.970	-7653.76	9321.99
	2.00	.00	9773.41*	3477.292	.017	1446.82	18100.00
		1.00	-834.12	3544.648	.970	-9321.99	7653.76
angryrt	.00	1.00	-12112.48*	3459.895	.002	-20397.41	-3827.55
		2.00	-14131.12*	3498.788	.000	-22509.18	-5753.05
	1.00	.00	12112.48*	3459.895	.002	3827.55	20397.41
		2.00	-2018.64	3566.561	.839	-10558.99	6521.71
	2.00	.00	14131.12*	3498.788	.000	5753.05	22509.18
		1.00	2018.64	3566.561	.839	-6521.71	10558.99
disgustedrt	.00	1.00	-10087.28*	4013.149	.037	-19697.01	-477.55
		2.00	-9644.13	4058.261	.052	-19361.89	73.62
	1.00	.00	10087.28*	4013.149	.037	477.55	19697.01
		2.00	443.15	4136.871	.994	-9462.84	10349.14
	2.00	.00	9644.13	4058.261	.052	-73.62	19361.89
		1.00	-443.15	4136.871	.994	-10349.14	9462.84
contemptfulrt	.00	1.00	-8947.36*	3057.826	.013	-16269.51	-1625.20
		2.00	-9257.64*	3092.199	.011	-16662.11	-1853.18
	1.00	.00	8947.36*	3057.826	.013	1625.20	16269.51
		2.00	-310.29	3152.096	.995	-7858.18	7237.60
	2.00	.00	9257.64*	3092.199	.011	1853.18	16662.11
		1.00	310.29	3152.096	.995	-7237.60	7858.18
surprisedrt	.00	1.00	-12074.04*	3132.593	.001	-19575.22	-4572.85

		2.00	-7097.80	3167.807	.071	-14683.31	487.71
	1.00	.00	12074.04*	3132.593	.001	4572.85	19575.22
		2.00	4976.24	3229.168	.278	-2756.20	12708.68
	2.00	.00	7097.80	3167.807	.071	-487.71	14683.31
		1.00	-4976.24	3229.168	.278	-12708.68	2756.20
	.00	1.00	-10060.75*	2697.248	.001	-16519.48	-3602.02
		2.00	-6598.70*	2727.569	.047	-13130.03	-67.37
fearfulrt	1.00	.00	10060.75*	2697.248	.001	3602.02	16519.48
		2.00	3462.05	2780.402	.431	-3195.79	10119.90
	2.00	.00	6598.70*	2727.569	.047	67.37	13130.03
		1.00	-3462.05	2780.402	.431	-10119.90	3195.79

Based on observed means.

The error term is Mean Square(Error) = 90793861.077.

*. The mean difference is significant at the

Study 4
Non-Verbal Gist
Accuracy

Descriptive Statistics

	group	Mean	Std. Deviation	N
exact	young	.9367	.09863	24
	young old	.9605	.04186	20
	old-old	.8673	.09187	22
	Total	.9208	.09071	66
semanticallyrelated	young	.0392	.06324	24
	young old	.0240	.03378	20
	old-old	.0927	.07408	22
	Total	.0524	.06622	66
functionallyrelated	young	.0217	.03749	24
	young old	.0115	.02134	20
	old-old	.0318	.03750	22
	Total	.0220	.03393	66
notrelated	young	.0033	.01129	24
	young old	.0040	.01231	20
	old-old	.0086	.01959	22
	Total	.0053	.01480	66

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[d]
Intercept	Pillai's Trace	1.000	2142154.155[b]	4.000	60.000	.000	1.000	8568616.621	1.000
	Wilks' Lambda	.000	2142154.155[b]	4.000	60.000	.000	1.000	8568616.621	1.000
	Hotelling's Trace	142810.277	2142154.155[b]	4.000	60.000	.000	1.000	8568616.621	1.000
	Roy's Largest Root	142810.277	2142154.155[b]	4.000	60.000	.000	1.000	8568616.621	1.000
group	Pillai's Trace	.232	2.002	8.000	122.000	.052	.116	16.014	.801
	Wilks' Lambda	.773	2.057[b]	8.000	120.000	.045	.121	16.456	.813
	Hotelling's Trace	.286	2.110	8.000	118.000	.040	.125	16.878	.824
	Roy's Largest Root	.259	3.950[c]	4.000	61.000	.006	.206	15.802	.882

a. Design: Intercept + group

b. Exact statistic

c. The statistic is an upper bound on F that yields a lower bound on the significance level.

d. Computed using alpha =

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[e]
Corrected Model	exact	.101[a]	2	.050	7.297	.001	.188	14.594	.926
	semanticallyrelated	.056[b]	2	.028	7.722	.001	.197	15.444	.940
	functionallyrelated	.004[c]	2	.002	1.934	.153	.058	3.867	.387
	notrelated	.000[d]	2	.000	.844	.435	.026	1.687	.189
Intercept	exact	55.733	1	55.733	8085.289	.000	.992	8085.289	1.000
	semanticallyrelated	.177	1	.177	48.781	.000	.436	48.781	1.000
	functionallyrelated	.031	1	.031	27.515	.000	.304	27.515	.999
	notrelated	.002	1	.002	8.447	.005	.118	8.447	.816
group	exact	.101	2	.050	7.297	.001	.188	14.594	.926
	semanticallyrelated	.056	2	.028	7.722	.001	.197	15.444	.940
	functionallyrelated	.004	2	.002	1.934	.153	.058	3.867	.387
	notrelated	.000	2	.000	.844	.435	.026	1.687	.189
Error	exact	.434	63	.007					
	semanticallyrelated	.229	63	.004					
	functionallyrelated	.071	63	.001					
	notrelated	.014	63	.000					
Total	exact	56.489	66						
	semanticallyrelated	.466	66						
	functionallyrelated	.107	66						
	notrelated	.016	66						
Corrected Total	exact	.535	65						
	semanticallyrelated	.285	65						
	functionallyrelated	.075	65						
	notrelated	.014	65						

a. R Squared = .188 (Adjusted R Squared = .162)

b. R Squared = .197 (Adjusted R Squared = .171)

c. R Squared = .058 (Adjusted R Squared = .028)

d. R Squared = .026 (Adjusted R Squared = -.005)

e. Computed using alpha =

Multiple Comparisons

Tukey HSD

Dependent Variable	(I) group	(J) group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
exact	young	young old	-.0238	.02514	.612	-.0842	.0365
		old-old	.0694*	.02451	.017	.0106	.1282
	young old	young	.0238	.02514	.612	-.0365	.0842
		old-old	.0932*	.02565	.002	.0317	.1548
	old-old	young	-.0694*	.02451	.017	-.1282	-.0106
		young old	-.0932*	.02565	.002	-.1548	-.0317
semanticallyrelated	young	young old	.0152	.01825	.685	-.0286	.0590
		old-old	-.0536*	.01779	.010	-.0963	-.0109
	young old	young	-.0152	.01825	.685	-.0590	.0286
		old-old	-.0687*	.01862	.001	-.1134	-.0240
	old-old	young	.0536*	.01779	.010	.0109	.0963
		young old	.0687*	.01862	.001	.0240	.1134
functionallyrelated	young	young old	.0102	.01013	.577	-.0141	.0345
		old-old	-.0102	.00987	.562	-.0339	.0136
	young old	young	-.0102	.01013	.577	-.0345	.0141
		old-old	-.0203	.01034	.129	-.0451	.0045
	old-old	young	.0102	.00987	.562	-.0136	.0339
		young old	.0203	.01034	.129	-.0045	.0451
notrelated	young	young old	-.0007	.00449	.988	-.0115	.0101
		old-old	-.0053	.00438	.451	-.0158	.0052
	young old	young	.0007	.00449	.988	-.0101	.0115
		old-old	-.0046	.00458	.573	-.0156	.0064
	old-old	young	.0053	.00438	.451	-.0052	.0158
		young old	.0046	.00458	.573	-.0064	.0156

Based on observed means.

The error term is Mean Square(Error) = .000.

*. The mean difference is significant at the

Non-Verbal Gist
Latency

Descriptive Statistics

	group	Mean	Std. Deviation	N
exactrt	young	1889.4088	457.32933	24
	young old	2397.4390	644.40580	20
	old-old	2769.1668	855.44788	22
	Total	2336.6100	755.06536	66
semanticallyrelatedrt	young	145.5479	222.30652	24
	young old	100.0725	188.47559	20
	old-old	439.7327	399.90107	22
	Total	229.8291	319.77072	66
functionallyrelatedrt	young	60.5496	104.04192	24
	young old	79.1540	187.46738	20
	old-old	101.8891	142.49627	22
	Total	79.9671	144.79421	66
notrelatedrt	young	33.4133	149.92957	24
	young old	11.6430	35.84640	20
	old-old	36.1482	83.92694	22
	Total	27.7279	103.54166	66

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[d]
Intercept	Pillai's Trace	.931	202.816[b]	4.000	60.000	.000	.931	811.263	1.000
	Wilks' Lambda	.069	202.816[b]	4.000	60.000	.000	.931	811.263	1.000
	Hotelling's Trace	13.521	202.816[b]	4.000	60.000	.000	.931	811.263	1.000
	Roy's Largest Root	13.521	202.816[b]	4.000	60.000	.000	.931	811.263	1.000
group	Pillai's Trace	.408	3.912	8.000	122.000	.000	.204	31.293	.988
	Wilks' Lambda	.623	3.999[b]	8.000	120.000	.000	.210	31.988	.989
	Hotelling's Trace	.553	4.082	8.000	118.000	.000	.217	32.653	.991
	Roy's Largest Root	.437	6.670[c]	4.000	61.000	.000	.304	26.681	.988

a. Design: Intercept + group

b. Exact statistic

c. The statistic is an upper bound on F that yields a lower bound on the significance level.

d. Computed using alpha =

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[e]
Corrected Model	exactrt	8990057.158[a]	2	4495028.579	10.089	.000	.243	20.179	.982
	semanticallyrelatedrt	1476524.854[b]	2	738262.427	8.996	.000	.222	17.993	.968
	functionallyrelatedrt	19634.803[c]	2	9817.401	.460	.633	.014	.921	.122
	notrelatedrt	7510.085[d]	2	3755.043	.343	.711	.011	.686	.103
Intercept	exactrt	363090004.939	1	363090004.939	814.974	.000	.928	814.974	1.000
	semanticallyrelatedrt	3425501.603	1	3425501.603	41.743	.000	.399	41.743	1.000
	functionallyrelatedrt	425660.037	1	425660.037	19.966	.000	.241	19.966	.993
	notrelatedrt	48090.103	1	48090.103	4.395	.040	.065	4.395	.542
group	exactrt	8990057.158	2	4495028.579	10.089	.000	.243	20.179	.982
	semanticallyrelatedrt	1476524.854	2	738262.427	8.996	.000	.222	17.993	.968
	functionallyrelatedrt	19634.803	2	9817.401	.460	.633	.014	.921	.122
	notrelatedrt	7510.085	2	3755.043	.343	.711	.011	.686	.103
Error	exactrt	28067983.206	63	445523.543					
	semanticallyrelatedrt	5169940.518	63	82062.548					
	functionallyrelatedrt	1343113.860	63	21319.268					
	notrelatedrt	689346.815	63	10942.013					
Total	exactrt	397401295.643	66						
	semanticallyrelatedrt	10132678.499	66						
	functionallyrelatedrt	1784801.534	66						
	notrelatedrt	747600.028	66						
Corrected Total	exactrt	37058040.364	65						
	semanticallyrelatedrt	6646465.372	65						
	functionallyrelatedrt	1362748.663	65						
	notrelatedrt	696856.900	65						

a. R Squared = .243 (Adjusted R Squared = .219)

b. R Squared = .222 (Adjusted R Squared = .197)

c. R Squared = .014 (Adjusted R Squared = -.017)

d. R Squared = .011 (Adjusted R Squared = -.021)

e. Computed using alpha =

Multiple Comparisons

Tukey HSD

Dependent Variable	(I) group	(J) group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
exactrt	young	young old	-508.0302*	202.08824	.038	-993.1078	-22.9527
		old-old	-879.7581*	197.01409	.000	-1352.6560	-406.8601
	young old	young	508.0302*	202.08824	.038	22.9527	993.1078
		old-old	-371.7278	206.22136	.177	-866.7262	123.2706
	old-old	young	879.7581*	197.01409	.000	406.8601	1352.6560
		young old	371.7278	206.22136	.177	-123.2706	866.7262
semanticallyrelatedrt	young	young old	45.4754	86.73177	.860	-162.7091	253.6599
		old-old	-294.1848*	84.55406	.003	-497.1421	-91.2275
	young old	young	-45.4754	86.73177	.860	-253.6599	162.7091
		old-old	-339.6602*	88.50561	.001	-552.1025	-127.2179
	old-old	young	294.1848*	84.55406	.003	91.2275	497.1421
		young old	339.6602*	88.50561	.001	127.2179	552.1025
functionallyrelatedrt	young	young old	-18.6044	44.20708	.907	-124.7158	87.5070
		old-old	-41.3395	43.09710	.605	-144.7866	62.1076
	young old	young	18.6044	44.20708	.907	-87.5070	124.7158
		old-old	-22.7351	45.11121	.870	-131.0167	85.5465
	old-old	young	41.3395	43.09710	.605	-62.1076	144.7866
		young old	22.7351	45.11121	.870	-85.5465	131.0167
notrelatedrt	young	young old	21.7703	31.67046	.772	-54.2491	97.7897
		old-old	-2.7348	30.87526	.996	-76.8455	71.3758
	young old	young	-21.7703	31.67046	.772	-97.7897	54.2491
		old-old	-24.5052	32.31818	.730	-102.0793	53.0690
	old-old	young	2.7348	30.87526	.996	-71.3758	76.8455
		young old	24.5052	32.31818	.730	-53.0690	102.0793

Based on observed means.

The error term is Mean Square(Error) = 10942.013.

*. The mean difference is significant at the

Verbal Gist

Descriptive Statistics

	group	Mean	Std. Deviation	N
Error_hit	young	.4911	.21301	24
	young old	.1917	.17121	20
	old-old	.2653	.28269	22
	Total	.3251	.25943	66
Error_related	young	.5990	.15484	24
	young old	.8938	.18997	20
	old-old	.8333	.22577	22
	Total	.7664	.22881	66

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[d]
Intercept	Pillai's Trace	.985	2030.797[b]	2.000	62.000	.000	.985	4061.594	1.000
	Wilks' Lambda	.015	2030.797[b]	2.000	62.000	.000	.985	4061.594	1.000
	Hotelling's Trace	65.510	2030.797[b]	2.000	62.000	.000	.985	4061.594	1.000
	Roy's Largest Root	65.510	2030.797[b]	2.000	62.000	.000	.985	4061.594	1.000
group	Pillai's Trace	.327	6.149	4.000	126.000	.000	.163	24.594	.985
	Wilks' Lambda	.674	6.766[b]	4.000	124.000	.000	.179	27.062	.992
	Hotelling's Trace	.483	7.373	4.000	122.000	.000	.195	29.492	.996
	Roy's Largest Root	.482	15.188[c]	2.000	63.000	.000	.325	30.376	.999

a. Design: Intercept + group

b. Exact statistic

c. The statistic is an upper bound on F that yields a lower bound on the significance level.

d. Computed using alpha =

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[c]
Corrected Model	Error_hit	1.096[a]	2	.548	10.531	.000	.251	21.063	.985
	Error_related	1.096[b]	2	.548	14.956	.000	.322	29.911	.999
Intercept	Error_hit	6.555	1	6.555	125.956	.000	.667	125.956	1.000
	Error_related	39.455	1	39.455	1077.198	.000	.945	1077.198	1.000
group	Error_hit	1.096	2	.548	10.531	.000	.251	21.063	.985
	Error_related	1.096	2	.548	14.956	.000	.322	29.911	.999
Error	Error_hit	3.279	63	.052					
	Error_related	2.308	63	.037					
Total	Error_hit	11.351	66						
	Error_related	42.168	66						
Corrected Total	Error_hit	4.375	65						
	Error_related	3.403	65						

a. R Squared = .251 (Adjusted R Squared = .227)

b. R Squared = .322 (Adjusted R Squared = .300)

c. Computed using alpha =

Multiple Comparisons

Tukey HSD

Dependent Variable	(I) group	(J) group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Error_hit	young	young old	.2994*	.06907	.000	.1337	.4652
		old-old	.2258*	.06734	.004	.0642	.3874
	young old	young	-.2994*	.06907	.000	-.4652	-.1337
		old-old	-.0736	.07048	.552	-.2428	.0955
	old-old	young	-.2258*	.06734	.004	-.3874	-.0642
		young old	.0736	.07048	.552	-.0955	.2428
Error_related	young	young old	-.2948*	.05794	.000	-.4339	-.1557
		old-old	-.2343*	.05649	.000	-.3699	-.0987
	young old	young	.2948*	.05794	.000	.1557	.4339
		old-old	.0605	.05913	.565	-.0814	.2024
	old-old	young	.2343*	.05649	.000	.0987	.3699
		young old	-.0605	.05913	.565	-.2024	.0814

Based on observed means.

The error term is Mean Square(Error) = .037.

*. The mean difference is significant at the

Study 5
Non-Verbal Implicit Memory

Descriptive Statistics

	group	Mean	Std. Deviation	N
Ty(1)	.00	6.54	1.933	24
	1.00	6.52	1.940	21
	2.00	6.29	1.875	21
	Total	6.45	1.891	66
Dy(1)	.00	3.29	1.654	24
	1.00	4.38	2.037	21
	2.00	4.57	1.938	21
	Total	4.05	1.933	66
Ty(2)	.00	7.00	2.022	24
	1.00	8.05	1.717	21
	2.00	7.71	1.231	21
	Total	7.56	1.738	66
Dy(2)	.00	4.75	1.726	24
	1.00	5.76	1.814	21
	2.00	5.43	1.912	21
	Total	5.29	1.838	66
Ty(3)	.00	6.71	2.528	24
	1.00	7.71	1.554	21
	2.00	7.38	1.884	21
	Total	7.24	2.069	66
Dy(3)	.00	5.08	2.185	24
	1.00	5.29	2.305	21
	2.00	6.62	1.936	21
	Total	5.64	2.223	66
Ty(4)	.00	8.17	1.786	24
	1.00	7.76	1.921	21
	2.00	7.90	1.338	21
	Total	7.95	1.686	66
Dy(4)	.00	5.13	1.650	24
	1.00	5.52	1.806	21
	2.00	6.71	1.901	21
	Total	5.76	1.882	66
Ty(5)	.00	8.08	1.998	24
	1.00	8.19	1.504	21
	2.00	7.81	1.834	21
	Total	8.03	1.780	66
Dy(5)	.00	6.17	2.599	24
	1.00	5.81	2.112	21

	2.00	6.95	1.564	21
	Total	6.30	2.177	66
Ty(6)	.00	6.58	1.767	24
	1.00	5.90	2.508	21
	2.00	6.43	2.521	21
	Total	6.32	2.254	66
Dy(6)	.00	4.54	2.021	24
	1.00	4.52	2.562	21
	2.00	4.95	2.334	21
	Total	4.67	2.276	66
Ty(7)	.00	8.88	1.541	24
	1.00	8.81	1.470	21
	2.00	8.52	1.778	21
	Total	8.74	1.582	66
Dy(7)	.00	7.25	2.289	24
	1.00	7.57	1.886	21
	2.00	7.95	1.627	21
	Total	7.58	1.962	66
Ty(8)	.00	9.08	1.349	24
	1.00	9.38	.865	21
	2.00	8.95	1.532	21
	Total	9.14	1.276	66
Dy(8)	.00	7.46	2.146	24
	1.00	7.98	2.520	21
	2.00	8.00	2.025	21
	Total	7.80	2.216	66

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[d]
trial	Pillai's Trace	.726	21.608[b]	7.000	57.000	.000	.726	151.255	1.000
	Wilks' Lambda	.274	21.608[b]	7.000	57.000	.000	.726	151.255	1.000
	Hotelling's Trace	2.654	21.608[b]	7.000	57.000	.000	.726	151.255	1.000
	Roy's Largest Root	2.654	21.608[b]	7.000	57.000	.000	.726	151.255	1.000
trial * group	Pillai's Trace	.188	.861	14.000	116.000	.602	.094	12.052	.518
	Wilks' Lambda	.819	.853[b]	14.000	114.000	.611	.095	11.936	.512
	Hotelling's Trace	.211	.844	14.000	112.000	.620	.095	11.818	.506
	Roy's Largest Root	.148	1.226[c]	7.000	58.000	.304	.129	8.579	.479
target	Pillai's Trace	.706	151.421[b]	1.000	63.000	.000	.706	151.421	1.000
	Wilks' Lambda	.294	151.421[b]	1.000	63.000	.000	.706	151.421	1.000
	Hotelling's Trace	2.404	151.421[b]	1.000	63.000	.000	.706	151.421	1.000
	Roy's Largest Root	2.404	151.421[b]	1.000	63.000	.000	.706	151.421	1.000
target * group	Pillai's Trace	.109	3.870[b]	2.000	63.000	.026	.109	7.739	.680
	Wilks' Lambda	.891	3.870[b]	2.000	63.000	.026	.109	7.739	.680
	Hotelling's Trace	.123	3.870[b]	2.000	63.000	.026	.109	7.739	.680
	Roy's Largest Root	.123	3.870[b]	2.000	63.000	.026	.109	7.739	.680
trial * target	Pillai's Trace	.299	3.470[b]	7.000	57.000	.004	.299	24.287	.947
	Wilks' Lambda	.701	3.470[b]	7.000	57.000	.004	.299	24.287	.947
	Hotelling's Trace	.426	3.470[b]	7.000	57.000	.004	.299	24.287	.947
	Roy's Largest Root	.426	3.470[b]	7.000	57.000	.004	.299	24.287	.947
trial * target * group	Pillai's Trace	.364	1.841	14.000	116.000	.040	.182	25.778	.905
	Wilks' Lambda	.668	1.820[b]	14.000	114.000	.044	.183	25.473	.900
	Hotelling's Trace	.449	1.797	14.000	112.000	.047	.183	25.164	.895
	Roy's Largest Root	.280	2.316[c]	7.000	58.000	.037	.218	16.213	.802

a. Design: Intercept + group

Within Subjects Design: trial + target + trial * target

b. Exact statistic

c. The statistic is an upper bound on F that yields a lower bound on the significance level.

d. Computed using alpha =

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
trial	Sphericity Assumed	1198.573	7	171.225	43.443	.000	.408	304.098	1.000
	Greenhouse-Geisser	1198.573	4.712	254.384	43.443	.000	.408	204.687	1.000
	Huynh-Feldt	1198.573	5.301	226.115	43.443	.000	.408	230.276	1.000
	Lower-bound	1198.573	1.000	1198.573	43.443	.000	.408	43.443	1.000
trial * group	Sphericity Assumed	46.504	14	3.322	.843	.622	.026	11.799	.544
	Greenhouse-Geisser	46.504	9.423	4.935	.843	.582	.026	7.942	.430
	Huynh-Feldt	46.504	10.601	4.387	.843	.594	.026	8.935	.461
	Lower-bound	46.504	2.000	23.252	.843	.435	.026	1.686	.188
Error(trial)	Sphericity Assumed	1738.161	441	3.941					
	Greenhouse-Geisser	1738.161	296.835	5.856					
	Huynh-Feldt	1738.161	333.945	5.205					
	Lower-bound	1738.161	63.000	27.590					
target	Sphericity Assumed	831.490	1	831.490	151.421	.000	.706	151.421	1.000
	Greenhouse-Geisser	831.490	1.000	831.490	151.421	.000	.706	151.421	1.000
	Huynh-Feldt	831.490	1.000	831.490	151.421	.000	.706	151.421	1.000
	Lower-bound	831.490	1.000	831.490	151.421	.000	.706	151.421	1.000
target * group	Sphericity Assumed	42.497	2	21.249	3.870	.026	.109	7.739	.680
	Greenhouse-Geisser	42.497	2.000	21.249	3.870	.026	.109	7.739	.680
	Huynh-Feldt	42.497	2.000	21.249	3.870	.026	.109	7.739	.680
	Lower-bound	42.497	2.000	21.249	3.870	.026	.109	7.739	.680
Error(target)	Sphericity Assumed	345.949	63	5.491					
	Greenhouse-Geisser	345.949	63.000	5.491					
	Huynh-Feldt	345.949	63.000	5.491					
	Lower-bound	345.949	63.000	5.491					

trial * target	Sphericity Assumed	45.991	7	6.570	4.849	.000	.071	33.940	.996
	Greenhouse-Geisser	45.991	6.128	7.506	4.849	.000	.071	29.710	.992
	Huynh-Feldt	45.991	7.000	6.570	4.849	.000	.071	33.940	.996
	Lower-bound	45.991	1.000	45.991	4.849	.031	.071	4.849	.583
trial * target * group	Sphericity Assumed	30.285	14	2.163	1.596	.077	.048	22.349	.878
	Greenhouse-Geisser	30.285	12.255	2.471	1.596	.088	.048	19.564	.841
	Huynh-Feldt	30.285	14.000	2.163	1.596	.077	.048	22.349	.878
	Lower-bound	30.285	2.000	15.142	1.596	.211	.048	3.193	.326
Error(trial*target)	Sphericity Assumed	597.588	441	1.355					
	Greenhouse-Geisser	597.588	386.037	1.548					
	Huynh-Feldt	597.588	441.000	1.355					
	Lower-bound	597.588	63.000	9.486					

a. Computed using alpha =

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intercept	48538.922	1	48538.922	2823.401	.000	.978	2823.401	1.000
group	40.036	2	20.018	1.164	.319	.036	2.329	.247
Error	1083.074	63	17.192					

a. Computed using alpha =

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Ty(1)	6.45	66	1.891	.233
	Dy(1)	4.05	66	1.933	.238
Pair 2	Ty(2)	7.56	66	1.738	.214
	Dy(2)	5.29	66	1.838	.226
Pair 3	Ty(3)	7.24	66	2.069	.255
	Dy(3)	5.64	66	2.223	.274
Pair 4	Ty(4)	7.95	66	1.686	.208
	Dy(4)	5.76	66	1.882	.232
Pair 5	Ty(5)	8.03	66	1.780	.219
	Dy(5)	6.30	66	2.177	.268
Pair 6	Ty(6)	6.32	66	2.254	.277
	Dy(6)	4.67	66	2.276	.280
Pair 7	Ty(7)	8.74	66	1.582	.195
	Dy(7)	7.58	66	1.962	.241
Pair 8	Ty(8)	9.14	66	1.276	.157
	Dy(8)	7.80	66	2.216	.273

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Ty(1) - Dy(1)	2.409	1.905	.235	1.941	2.877	10.272	65	.000
Pair 2	Ty(2) - Dy(2)	2.273	1.828	.225	1.823	2.722	10.103	65	.000
Pair 3	Ty(3) - Dy(3)	1.606	2.218	.273	1.061	2.151	5.883	65	.000
Pair 4	Ty(4) - Dy(4)	2.197	2.121	.261	1.676	2.718	8.415	65	.000
Pair 5	Ty(5) - Dy(5)	1.727	2.195	.270	1.188	2.267	6.394	65	.000
Pair 6	Ty(6) - Dy(6)	1.652	1.802	.222	1.209	2.094	7.447	65	.000
Pair 7	Ty(7) - Dy(7)	1.167	1.742	.214	.739	1.595	5.442	65	.000
Pair 8	Ty(8) - Dy(8)	1.339	1.946	.240	.860	1.817	5.588	65	.000

Paired Samples Statistics[a]

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Ty(1)	6.29	21	1.875	.409
	Dy(1)	4.57	21	1.938	.423
Pair 2	Ty(2)	7.71	21	1.231	.269
	Dy(2)	5.43	21	1.912	.417
Pair 3	Ty(3)	7.38	21	1.884	.411
	Dy(3)	6.62	21	1.936	.422
Pair 4	Ty(4)	7.90	21	1.338	.292
	Dy(4)	6.71	21	1.901	.415
Pair 5	Ty(5)	7.81	21	1.834	.400
	Dy(5)	6.95	21	1.564	.341
Pair 6	Ty(6)	6.43	21	2.521	.550
	Dy(6)	4.95	21	2.334	.509
Pair 7	Ty(7)	8.52	21	1.778	.388
	Dy(7)	7.95	21	1.627	.355
Pair 8	Ty(8)	8.95	21	1.532	.334
	Dy(8)	8.00	21	2.025	.442

a. group = 2.00

Paired Samples Test[a]

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Ty(1) - Dy(1)	1.714	1.189	.260	1.173	2.256	6.606	20	.000
Pair 2	Ty(2) - Dy(2)	2.286	1.617	.353	1.550	3.022	6.478	20	.000
Pair 3	Ty(3) - Dy(3)	.762	1.868	.408	-.089	1.612	1.869	20	.076
Pair 4	Ty(4) - Dy(4)	1.190	1.601	.349	.462	1.919	3.408	20	.003
Pair 5	Ty(5) - Dy(5)	.857	1.276	.278	.276	1.438	3.078	20	.006
Pair 6	Ty(6) - Dy(6)	1.476	1.504	.328	.792	2.161	4.498	20	.000
Pair 7	Ty(7) - Dy(7)	.571	1.287	.281	-.015	1.157	2.034	20	.055
Pair 8	Ty(8) - Dy(8)	.952	1.359	.297	.334	1.571	3.211	20	.004

a. group = 2.00

Descriptive Statistics

Dependent Variable: Ty(7)

group	Mean	Std. Deviation	N
.00	8.88	1.541	24
1.00	8.81	1.470	21
2.00	8.52	1.778	21
Total	8.74	1.582	66

Tests of Between-Subjects Effects

Dependent Variable: Ty(7)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[b]
Corrected Model	1.520[a]	2	.760	.297	.744	.009	.594	.095
Intercept	5017.187	1	5017.187	1962.014	.000	.969	1962.014	1.000
group	1.520	2	.760	.297	.744	.009	.594	.095
Error	161.101	63	2.557					
Total	5207.000	66						
Corrected Total	162.621	65						

a. R Squared = .009 (Adjusted R Squared = -.022)

b. Computed using alpha =

Descriptive Statistics

Dependent Variable: Dy(7)

group	Mean	Std. Deviation	N
.00	7.25	2.289	24
1.00	7.57	1.886	21
2.00	7.95	1.627	21
Total	7.58	1.962	66

Tests of Between-Subjects Effects

Dependent Variable: Dy(7)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[b]
Corrected Model	5.526[a]	2	2.763	.712	.495	.022	1.423	.165
Intercept	3788.374	1	3788.374	975.765	.000	.939	975.765	1.000
group	5.526	2	2.763	.712	.495	.022	1.423	.165
Error	244.595	63	3.882					
Total	4038.000	66						
Corrected Total	250.121	65						

a. R Squared = .022 (Adjusted R Squared = -.009)

b. Computed using alpha =

Descriptive Statistics

Dependent Variable: Ty(8)

group	Mean	Std. Deviation	N
.00	9.08	1.349	24
1.00	9.38	.865	21
2.00	8.95	1.532	21
Total	9.14	1.276	66

Tests of Between-Subjects Effects

Dependent Variable: Ty(8)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[b]
Corrected Model	2.035[a]	2	1.017	.618	.542	.019	1.236	.149
Intercept	5490.486	1	5490.486	3334.364	.000	.981	3334.364	1.000
group	2.035	2	1.017	.618	.542	.019	1.236	.149
Error	103.738	63	1.647					
Total	5615.000	66						
Corrected Total	105.773	65						

a. R Squared = .019 (Adjusted R Squared = -.012)

b. Computed using alpha =

Descriptive Statistics

Dependent Variable: Dy(8)

group	Mean	Std. Deviation	N
.00	7.46	2.146	24
1.00	7.98	2.520	21
2.00	8.00	2.025	21
Total	7.80	2.216	66

Tests of Between-Subjects Effects

Dependent Variable: Dy(8)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[b]
Corrected Model	4.347[a]	2	2.174	.435	.649	.014	.870	.118
Intercept	4013.825	1	4013.825	802.829	.000	.927	802.829	1.000
group	4.347	2	2.174	.435	.649	.014	.870	.118
Error	314.975	63	5.000					
Total	4332.423	66						
Corrected Total	319.322	65						

a. R Squared = .014 (Adjusted R Squared = -.018)

b. Computed using alpha =

Descriptive Statistics[a]

	Mean	Std. Deviation	N
Ty(1)	6.54	1.933	24
Ty(2)	7.00	2.022	24
Ty(3)	6.71	2.528	24
Ty(4)	8.17	1.786	24
Ty(5)	8.08	1.998	24
Ty(6)	6.58	1.767	24
Ty(7)	8.88	1.541	24
Ty(8)	9.08	1.349	24

a. group = .00

Multivariate Tests[a,b]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[d]
trial	Pillai's Trace	.699	5.653[c]	7.000	17.000	.002	.699	39.572	.982
	Wilks' Lambda	.301	5.653[c]	7.000	17.000	.002	.699	39.572	.982
	Hotelling's Trace	2.328	5.653[c]	7.000	17.000	.002	.699	39.572	.982
	Roy's Largest Root	2.328	5.653[c]	7.000	17.000	.002	.699	39.572	.982

a. group = .00

b. Design: Intercept

Within Subjects Design: trial

c. Exact statistic

d. Computed using alpha =

Tests of Within-Subjects Effects[a]

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[b]
trial	Sphericity Assumed	184.370	7	26.339	10.516	.000	.314	73.610	1.000
	Greenhouse-Geisser	184.370	4.115	44.800	10.516	.000	.314	43.276	1.000
	Huynh-Feldt	184.370	5.124	35.980	10.516	.000	.314	53.885	1.000
	Lower-bound	184.370	1.000	184.370	10.516	.004	.314	10.516	.874
Error(trial)	Sphericity Assumed	403.255	161	2.505					
	Greenhouse-Geisser	403.255	94.655	4.260					
	Huynh-Feldt	403.255	117.859	3.422					
	Lower-bound	403.255	23.000	17.533					

a. group = .00

b. Computed using alpha =

Descriptive Statistics[a]

	Mean	Std. Deviation	N
Ty(1)	6.52	1.940	21
Ty(2)	8.05	1.717	21
Ty(3)	7.71	1.554	21
Ty(4)	7.76	1.921	21
Ty(5)	8.19	1.504	21
Ty(6)	5.90	2.508	21
Ty(7)	8.81	1.470	21
Ty(8)	9.38	.865	21

a. group = 1.00

Multivariate Tests[a,b]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[d]
trial	Pillai's Trace	.743	5.776[c]	7.000	14.000	.003	.743	40.431	.974
	Wilks' Lambda	.257	5.776[c]	7.000	14.000	.003	.743	40.431	.974
	Hotelling's Trace	2.888	5.776[c]	7.000	14.000	.003	.743	40.431	.974
	Roy's Largest Root	2.888	5.776[c]	7.000	14.000	.003	.743	40.431	.974

a. group = 1.00

b. Design: Intercept

Within Subjects Design: trial

c. Exact statistic

d. Computed using alpha =

Tests of Within-Subjects Effects[a]

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[b]
trial	Sphericity Assumed	188.185	7	26.884	11.063	.000	.356	77.444	1.000
	Greenhouse-Geisser	188.185	3.636	51.754	11.063	.000	.356	40.228	1.000
	Huynh-Feldt	188.185	4.544	41.413	11.063	.000	.356	50.273	1.000
	Lower-bound	188.185	1.000	188.185	11.063	.003	.356	11.063	.885
Error(trial)	Sphericity Assumed	340.190	140	2.430					
	Greenhouse-Geisser	340.190	72.723	4.678					
	Huynh-Feldt	340.190	90.882	3.743					
	Lower-bound	340.190	20.000	17.010					

a. group = 1.00

b. Computed using alpha =

Descriptive Statistics[a]

	Mean	Std. Deviation	N
Ty(1)	6.29	1.875	21
Ty(2)	7.71	1.231	21
Ty(3)	7.38	1.884	21
Ty(4)	7.90	1.338	21
Ty(5)	7.81	1.834	21
Ty(6)	6.43	2.521	21
Ty(7)	8.52	1.778	21
Ty(8)	8.95	1.532	21

a. group = 2.00

Multivariate Tests[a,b]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[d]
trial	Pillai's Trace	.711	4.911[c]	7.000	14.000	.006	.711	34.376	.945
	Wilks' Lambda	.289	4.911[c]	7.000	14.000	.006	.711	34.376	.945
	Hotelling's Trace	2.455	4.911[c]	7.000	14.000	.006	.711	34.376	.945
	Roy's Largest Root	2.455	4.911[c]	7.000	14.000	.006	.711	34.376	.945

a. group = 2.00

b. Design: Intercept

Within Subjects Design: trial

c. Exact statistic

d. Computed using alpha =

Tests of Within-Subjects Effects[a]

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[b]
trial	Sphericity Assumed	125.470	7	17.924	8.143	.000	.289	57.003	1.000
	Greenhouse-Geisser	125.470	4.155	30.198	8.143	.000	.289	33.835	.998
	Huynh-Feldt	125.470	5.380	23.320	8.143	.000	.289	43.815	1.000
	Lower-bound	125.470	1.000	125.470	8.143	.010	.289	8.143	.775
Error(trial)	Sphericity Assumed	308.155	140	2.201					
	Greenhouse-Geisser	308.155	83.099	3.708					
	Huynh-Feldt	308.155	107.609	2.864					
	Lower-bound	308.155	20.000	15.408					

a. group = 2.00

b. Computed using alpha =

Descriptive Statistics[a]

	Mean	Std. Deviation	N
Dy(1)	3.29	1.654	24
Dy(2)	4.75	1.726	24
Dy(3)	5.08	2.185	24
Dy(4)	5.13	1.650	24
Dy(5)	6.17	2.599	24
Dy(6)	4.54	2.021	24
Dy(7)	7.25	2.289	24
Dy(8)	7.46	2.146	24

a. group = .00

Multivariate Tests[a,b]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[d]
trial	Pillai's Trace	.814	10.599[c]	7.000	17.000	.000	.814	74.192	1.000
	Wilks' Lambda	.186	10.599[c]	7.000	17.000	.000	.814	74.192	1.000
	Hotelling's Trace	4.364	10.599[c]	7.000	17.000	.000	.814	74.192	1.000
	Roy's Largest Root	4.364	10.599[c]	7.000	17.000	.000	.814	74.192	1.000

a. group = .00

b. Design: Intercept

Within Subjects Design: trial

c. Exact statistic

d. Computed using alpha =

Tests of Within-Subjects Effects[a]

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[b]
trial	Sphericity Assumed	336.000	7	48.000	16.994	.000	.425	118.958	1.000
	Greenhouse-Geisser	336.000	4.044	83.078	16.994	.000	.425	68.730	1.000
	Huynh-Feldt	336.000	5.015	66.997	16.994	.000	.425	85.227	1.000
	Lower-bound	336.000	1.000	336.000	16.994	.000	.425	16.994	.976
Error(trial)	Sphericity Assumed	454.750	161	2.825					
	Greenhouse-Geisser	454.750	93.021	4.889					
	Huynh-Feldt	454.750	115.348	3.942					
	Lower-bound	454.750	23.000	19.772					

a. group = .00

b. Computed using alpha =

Descriptive Statistics[a]

	Mean	Std. Deviation	N
Dy(1)	4.38	2.037	21
Dy(2)	5.76	1.814	21
Dy(3)	5.29	2.305	21
Dy(4)	5.52	1.806	21
Dy(5)	5.81	2.112	21
Dy(6)	4.52	2.562	21
Dy(7)	7.57	1.886	21
Dy(8)	7.98	2.520	21

a. group = 1.00

Multivariate Tests[a,b]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[d]
trial	Pillai's Trace	.777	6.949[c]	7.000	14.000	.001	.777	48.643	.991
	Wilks' Lambda	.223	6.949[c]	7.000	14.000	.001	.777	48.643	.991
	Hotelling's Trace	3.474	6.949[c]	7.000	14.000	.001	.777	48.643	.991
	Roy's Largest Root	3.474	6.949[c]	7.000	14.000	.001	.777	48.643	.991

a. group = 1.00

b. Design: Intercept

Within Subjects Design: trial

c. Exact statistic

d. Computed using alpha =

Tests of Within-Subjects Effects[a]

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[b]
trial	Sphericity Assumed	249.172	7	35.596	9.953	.000	.332	69.674	1.000
	Greenhouse-Geisser	249.172	4.265	58.428	9.953	.000	.332	42.448	1.000
	Huynh-Feldt	249.172	5.564	44.780	9.953	.000	.332	55.384	1.000
	Lower-bound	249.172	1.000	249.172	9.953	.005	.332	9.953	.851
Error(trial)	Sphericity Assumed	500.673	140	3.576					
	Greenhouse-Geisser	500.673	85.292	5.870					
	Huynh-Feldt	500.673	111.286	4.499					
	Lower-bound	500.673	20.000	25.034					

a. group = 1.00

b. Computed using alpha =

Descriptive Statistics[a]

	Mean	Std. Deviation	N
Dy(1)	4.57	1.938	21
Dy(2)	5.43	1.912	21
Dy(3)	6.62	1.936	21
Dy(4)	6.71	1.901	21
Dy(5)	6.95	1.564	21
Dy(6)	4.95	2.334	21
Dy(7)	7.95	1.627	21
Dy(8)	8.00	2.025	21

a. group = 2.00

Multivariate Tests[a,b]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[d]
trial	Pillai's Trace	.765	6.509[c]	7.000	14.000	.002	.765	45.565	.987
	Wilks' Lambda	.235	6.509[c]	7.000	14.000	.002	.765	45.565	.987
	Hotelling's Trace	3.255	6.509[c]	7.000	14.000	.002	.765	45.565	.987
	Roy's Largest Root	3.255	6.509[c]	7.000	14.000	.002	.765	45.565	.987

a. group = 2.00

b. Design: Intercept

Within Subjects Design: trial

c. Exact statistic

d. Computed using alpha =

Tests of Within-Subjects Effects[a]

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[b]
trial	Sphericity Assumed	247.899	7	35.414	15.082	.000	.430	105.577	1.000
	Greenhouse-Geisser	247.899	4.690	52.858	15.082	.000	.430	70.735	1.000
	Huynh-Feldt	247.899	6.302	39.335	15.082	.000	.430	95.053	1.000
	Lower-bound	247.899	1.000	247.899	15.082	.001	.430	15.082	.958
Error(trial)	Sphericity Assumed	328.726	140	2.348					
	Greenhouse-Geisser	328.726	93.798	3.505					
	Huynh-Feldt	328.726	126.045	2.608					
	Lower-bound	328.726	20.000	16.436					

a. group = 2.00

b. Computed using alpha =

Verbal Implicit Memory
Accuracy

Descriptive Statistics

	group	Mean	Std. Deviation	N
oldhicor	.00	10.46	3.021	24
	1.00	9.10	2.644	21
	2.00	8.52	2.316	21
	Total	9.41	2.779	66
old words(studied low frequency correct)	.00	3.71	2.116	24
	1.00	3.59	1.829	21
	2.00	3.05	2.617	21
	Total	3.46	2.192	66

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[c]
freq	Pillai's Trace	.815	277.964[b]	1.000	63.000	.000	.815	277.964	1.000
	Wilks' Lambda	.185	277.964[b]	1.000	63.000	.000	.815	277.964	1.000
	Hotelling's Trace	4.412	277.964[b]	1.000	63.000	.000	.815	277.964	1.000
	Roy's Largest Root	4.412	277.964[b]	1.000	63.000	.000	.815	277.964	1.000
freq * group	Pillai's Trace	.044	1.460[b]	2.000	63.000	.240	.044	2.920	.301
	Wilks' Lambda	.956	1.460[b]	2.000	63.000	.240	.044	2.920	.301
	Hotelling's Trace	.046	1.460[b]	2.000	63.000	.240	.044	2.920	.301
	Roy's Largest Root	.046	1.460[b]	2.000	63.000	.240	.044	2.920	.301

a. Design: Intercept + group

Within Subjects Design: freq

b. Exact statistic

c. Computed using alpha =

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
freq	Sphericity Assumed	1148.873	1	1148.873	277.964	.000	.815	277.964	1.000
	Greenhouse-Geisser	1148.873	1.000	1148.873	277.964	.000	.815	277.964	1.000
	Huynh-Feldt	1148.873	1.000	1148.873	277.964	.000	.815	277.964	1.000
	Lower-bound	1148.873	1.000	1148.873	277.964	.000	.815	277.964	1.000
freq * group	Sphericity Assumed	12.070	2	6.035	1.460	.240	.044	2.920	.301
	Greenhouse-Geisser	12.070	2.000	6.035	1.460	.240	.044	2.920	.301
	Huynh-Feldt	12.070	2.000	6.035	1.460	.240	.044	2.920	.301
	Lower-bound	12.070	2.000	6.035	1.460	.240	.044	2.920	.301
Error(freq)	Sphericity Assumed	260.390	63	4.133					
	Greenhouse-Geisser	260.390	63.000	4.133					
	Huynh-Feldt	260.390	63.000	4.133					
	Lower-bound	260.390	63.000	4.133					

a. Computed using alpha =

Multiple Comparisons

Measure: MEASURE_1

Tukey HSD

(I) group	(J) group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
.00	1.00	.74	.597	.432	-.69	2.18
	2.00	1.30	.597	.084	-.14	2.73
1.00	.00	-.74	.597	.432	-2.18	.69
	2.00	.55	.617	.643	-.93	2.04
2.00	.00	-1.30	.597	.084	-2.73	.14
	1.00	-.55	.617	.643	-2.04	.93

Based on observed means.

The error term is Mean Square(Error) = 3.995.

Correlations

		newacccentered	age
newacccentered	Pearson Correlation	1	-.279*
	Sig. (1-tailed)		.012
	N	66	66
age	Pearson Correlation	-.279*	1
	Sig. (1-tailed)	.012	
	N	66	66

*. Correlation is significant at the 0.05 level (1-tailed).

Verbal Implicit Memory
Latency

Descriptive Statistics

	group	Mean	Std. Deviation	N
old words(high frequency correct lat)	.00	2228.416667	896.5906883	24
	1.00	3048.333333	901.6571041	21
	2.00	4318.904762	1866.5298526	21
	Total	3154.454545	1537.8303416	66
old words(low frequency correct latency)	.00	2766.625000	1219.3883646	24
	1.00	3487.333333	1278.4888867	21
	2.00	7441.047619	4713.1510635	21
	Total	4483.257576	3478.3670011	66

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[c]
freq	Pillai's Trace	.229	18.735[b]	1.000	63.000	.000	.229	18.735	.989
	Wilks' Lambda	.771	18.735[b]	1.000	63.000	.000	.229	18.735	.989
	Hotelling's Trace	.297	18.735[b]	1.000	63.000	.000	.229	18.735	.989
	Roy's Largest Root	.297	18.735[b]	1.000	63.000	.000	.229	18.735	.989
freq * group	Pillai's Trace	.194	7.568[b]	2.000	63.000	.001	.194	15.135	.935
	Wilks' Lambda	.806	7.568[b]	2.000	63.000	.001	.194	15.135	.935
	Hotelling's Trace	.240	7.568[b]	2.000	63.000	.001	.194	15.135	.935
	Roy's Largest Root	.240	7.568[b]	2.000	63.000	.001	.194	15.135	.935

a. Design: Intercept + group

Within Subjects Design: freq

b. Exact statistic

c. Computed using alpha =

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
freq	Sphericity Assumed	61373614.581	1	61373614.581	18.735	.000	.229	18.735	.989
	Greenhouse-Geisser	61373614.581	1.000	61373614.581	18.735	.000	.229	18.735	.989
	Huynh-Feldt	61373614.581	1.000	61373614.581	18.735	.000	.229	18.735	.989
	Lower-bound	61373614.581	1.000	61373614.581	18.735	.000	.229	18.735	.989
freq * group	Sphericity Assumed	49582559.955	2	24791279.977	7.568	.001	.194	15.135	.935
	Greenhouse-Geisser	49582559.955	2.000	24791279.977	7.568	.001	.194	15.135	.935
	Huynh-Feldt	49582559.955	2.000	24791279.977	7.568	.001	.194	15.135	.935
	Lower-bound	49582559.955	2.000	24791279.977	7.568	.001	.194	15.135	.935
Error(freq)	Sphericity Assumed	206385680.265	63	3275963.179					
	Greenhouse-Geisser	206385680.265	63.000	3275963.179					
	Huynh-Feldt	206385680.265	63.000	3275963.179					
	Lower-bound	206385680.265	63.000	3275963.179					

a. Computed using alpha =

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intercept	1981139548.986	1	1981139548.986	305.009	.000	.829	305.009	1.000
group	274981859.476	2	137490929.738	21.168	.000	.402	42.335	1.000
Error	409207245.289	63	6495353.100					

a. Computed using alpha =

Multiple Comparisons

Measure: MEASURE_1

Tukey HSD

(I) group	(J) group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
.00	1.00	-770.312500	538.4896661	.332	-2062.863059	522.238059
	2.00	-3382.455357*	538.4896661	.000	-4675.005917	-2089.904798
1.00	.00	770.312500	538.4896661	.332	-522.238059	2062.863059
	2.00	-2612.142857*	556.1497357	.000	-3947.083335	-1277.202380
2.00	.00	3382.455357*	538.4896661	.000	2089.904798	4675.005917
	1.00	2612.142857*	556.1497357	.000	1277.202380	3947.083335

Based on observed means.

The error term is Mean Square(Error) = 3247676.550.

*. The mean difference is significant at the

Explicit Memory
Mean Span

Descriptive Statistics

Dependent Variable: span

group	Mean	Std. Deviation	N
.00	7.2500	1.07663	24
1.00	6.9810	1.24081	21
2.00	6.0095	1.19411	21
Total	6.7697	1.26843	66

Tests of Between-Subjects Effects

Dependent Variable: span

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[b]
Corrected Model	18.609[a]	2	9.304	6.818	.002	.178	13.637	.908
Intercept	2992.422	1	2992.422	2192.876	.000	.972	2192.876	1.000
group	18.609	2	9.304	6.818	.002	.178	13.637	.908
Error	85.970	63	1.365					
Total	3129.280	66						
Corrected Total	104.579	65						

a. R Squared = .178 (Adjusted R Squared = .152)

b. Computed using alpha =

Multiple Comparisons

Dependent Variable: span

Tukey HSD

(I) group	(J) group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
.00	1.00	.2690	.34906	.722	-.5688	1.1069
	2.00	1.2405*	.34906	.002	.4026	2.0783
1.00	.00	-.2690	.34906	.722	-1.1069	.5688
	2.00	.9714*	.36050	.024	.1061	1.8368
2.00	.00	-1.2405*	.34906	.002	-2.0783	-.4026
	1.00	-.9714*	.36050	.024	-1.8368	-.1061

Based on observed means.

The error term is Mean Square(Error) = 1.365.

*. The mean difference is significant at the

Mean Latency

Descriptive Statistics

Dependent Variable: latency

group	Mean	Std. Deviation	N
.00	6.9818	1.02577	24
1.00	7.4063	.71594	21
2.00	7.3669	1.20744	21
Total	7.2394	1.00865	66

Tests of Between-Subjects Effects

Dependent Variable: latency

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[b]
Corrected Model	2.519[a]	2	1.260	1.248	.294	.038	2.495	.262
Intercept	3457.031	1	3457.031	3423.873	.000	.982	3423.873	1.000
group	2.519	2	1.260	1.248	.294	.038	2.495	.262
Error	63.610	63	1.010					
Total	3525.146	66						
Corrected Total	66.129	65						

a. R Squared = .038 (Adjusted R Squared = .008)

b. Computed using alpha =